U.S. DEPARTMENT OF COMMERCE
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PB-272 267

# Assessment in Industrial Hazardous Waste Management Petroleum Re-Refining Industry

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Prepared for

Environmental Protection Agency, Washington, D C Office of Solid Waste Management Programs

Jun 77

PB 272 267

# ASSESSMENT OF INDUSTRIAL HAZARDOUS WASTE MANAGEMENT
## PETROLEUM RE-REFINING INDUSTRY

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U.S. ENVIRONMENTAL PROTECTION AGENCY

1977

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BIBLIOGRAPHIC DATA SHEET

1. Report No.

2.

3. PB272267

4. Title and Subtitle

Assessment of Industrial Hazardous Waste Mgmt.- Petroleum Re-refining Industry

5. Report Date

June 1977

6.

7. Author(s)

John W. Swain

8. Performing Organization Rept. No.

9. Performing Organization Name and Address

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10. Project/Task/Work Unit No.

11. Contract/Grant No.

12. Sponsoring Organization Name and Address

EPA, Hazardous Waste Management Division
Office of Solid Waste
Washington, D.C. 20460

13. Type of Report & Period Covered

Final
Jan. 1976- Nov 1976

14. 2 xr/81

15. Supplementary Notes

EPA Project Officer - M. Straus

16. Abstracts

This study describes hazardous waste generation and management in the petroleum rerefining industry (SIC 2992) - the rerefining of waste oils for use as lubricants and as fuel. The industry's wastes contain such potentially hazardous contaminants as heavy metals, phenols and potentially carcinogenic aromatic hydrocarbons. The report surveys industry characteristics, quantity and character of its potentially hazardous wastes, treatment and disposal technology, and attendant costs. Projections for the production of rerefined oil and generation of wastes have been made for 1977 and 1983.

17. Key Words and Document Analysis. 17a. Descriptors

- petroleum re-refining
- hazardous waste
- waste oil
- disposal and treatment technology
- disposal and treatment costs
- industrial wastes
- waste treatment
- sludge, spent clay, process water

17b. Identifiers/Open-Ended Terms

17c. COSATI Field/Group

18. Availability Statement

19. Security Class (This Report)
UNCLASSIFIED

20. Security Class (This Page)
UNCLASSIFIED

21. No. of Pages
162

22. Price
A08 - A01

This report has been reviewed by the U.S. Environmental Protection Agency and approved for publication. Its publication does not signify that the contents necessarily reflect the views and policies of the U.S. Environmental Protection Agency, nor does mention of commercial products constitute endorsement or recommendation for use by the U.S. Government.

An environmental protection publication (SW-144c) in the solid waste management series.

# ACKNOWLEDGMENTS

This report is the result of a study of potentially hazardous wastes generated by the petroleum rerefining industry. Included is information relating to quantities of wastes produced, current treatment and disposal technology, and costs of treatment and disposal as well as potential improved process methods.

We are grateful for the invaluable suggestions, advice, and assistance of Mr. Matthew A. Straus, Dr. Shelly J. Williamson, and Mr. Timothy Fields, Jr., of the Hazardous Waste Management Division, Office of Solid Waste, U.S. Environmental Protection Agency.

This study could not have been accomplished without the cooperation and assistance of all but two of the commercial rerefiners in the U.S. Particular appreciation is due Mr. Belton R. Williams of the Motor Oils Refining Company, Mr. H. R. Robertson of the Jackson Oil Company, Mr. A. L. Warden of the Warden Oil Company, Mr. William Judd and Mr. E. E. Fisher of the Texas American Oil Company, and Mr. Lester R. Schurr of Berks Associates as well as Mr. Duane H. Ekedahl of the Association of Petroleum Rerefiners.

A very special acknowledgment must be made to Sally B. Swain who, cheerfully, prepared the several drafts of this report.

John W. Swain
Consultant

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## 1.0 Introduction

Resource recovery has become a matter of great importance in worldwide public awareness. Wastes from manufacturing sources generated in tremendous quantities are often a threat to our environment and, when not recycled, irretrievably deplete our finite resources.

This study addresses potentially hazardous wastes generated by the petroleum rerefining industry. However, the underlying resource recovery potential is present. There is little argument today against the preference for rerefining of waste lubricating oils as opposed to their use as fuel. Rerefining has been practiced since 1916. Civilian and military aircraft engine oils were rerefined until 1949. 29,000,000 hours of engine flight time was accumulated using rerefined oils. 1,174,810 gallons, representing 25 percent of total lubricating oil demand, was used by the U.S. Air Force in 1949.

A potential shortage of lubricating oils is predicted by most authorities. The effect on transportation vehicles is readily apparent. However, the effect on industry, which uses petroleum oils for many other purposes, as well as lubrication, could be even more severe.

However, use of waste oils as fuel, processed to remove contaminants which cause air pollution, is certainly preferable to dumping of raw waste oils on land or into sewers or open drains.

Thus, potentially hazardous wastes are generated in the rerefining of waste oils for lubricating use as well as the processing of waste oils for use as environmentally acceptable fuel. These wastes contain potentially hazardous contaminants such as heavy metals, phenols and potentially carcinogenic aromatic hydrocarbons.

This study report attempts to qualify and quantify the potentially hazardous wastes generated by the petroleum rerefining industry in the United States. It further surveys the industry characteristics as well as the treatment and disposal technology and costs for its wastes. Projected production of rerefined oil and generation of wastes, using the best data available, have been made for 1977 and 1983.

## 2.0 Executive Summary

### 2.1 Introduction

This report is the result of a study commissioned by the U.S. Environmental Protection Agency (EPA) to assess "Industrial Hazardous Waste Management Practices in the Petroleum Rerefining Industry" (SIC 2992). This industry study is one of a series sponsored by the Office of Solid Waste, Hazardous Waste Management Division. The studies were conducted for information purposes only and not in response to a Congressional regulatory mandate. The studies serve to provide EPA with: (1) an initial data base concerning current and projected types and quantities of industrial wastes and applicable disposal methods and costs; (2) a data base for technical assistance activities; and (3) a background for guidelines development activities.

The definition of "potentially hazardous waste" in this study was developed based upon contractor investigations and professional judgment. This definition does not necessarily reflect EPA policy since such a definition, especially in a regulatory context, must be broadly applicable to widely differing types of waste streams. Obviously, the presence of a toxic substance should not be the major determinant of hazardousness if there were mechanisms to represent or illustrate actual effects of wastes in specified environments. Thus, the reader is cautioned that the data presented in this report constitute only the contractor's assessment of the hazardous waste management problem in this industry.

It has been estimated that 1.1 billion gallons of waste oil were generated in 1972.[1] Using the same waste oil factors, it is estimated from 1975 sales data that 1.26 billion gallons were generated in 1975. The components of these estimates are presented below.

Waste Oil Generation (U.S. 1972, 1975) (Gallons-$10^6$)

| | 1972 | 1975 |
|---|---|---|
| Automotive lube oils | 616 | 673 |
| Industrial and aviation oils | 394 | 458 |
| Other industrial oils | 87 | 113 |
| Lube oils purchased by U.S. | 18 | 16 |
| Total | 1,115 | 1,260 |

These wastes can present significant environmental hazards from unacceptable disposal methods, such as:

1. Uncontrolled burning, as a fuel, with consequent emission of lead and other heavy metals.

2. Uncontrolled dumping on land with consequent contamination of ground water by leaching and contamination of surface water by run-off.

3. Dumping in waterways, which can result in danger to fresh water and marine organisms, and affect recreational and drinking water quality.

4. Road oiling which can result in undesirable

environmental effects via runoff into surface waters and absorption into the soil and plant life.

High fuel prices in recent years have had the effect of diverting a major quantity of waste oil from rerefining to some form of energy use, such as a fuel.

Oil rerefining produces lubricating oils which have a higher economic value than fuel oils. Shortages of lubricating oil products are projected by most authorities.[2] One significant problem affecting the industry is the generation and disposal of process wastes which concentrate the hazardous materials contained in waste oils.

## 2.2 Purpose of the Study

This study has been conducted to:

1. Provide a characterization of the current petroleum rerefining industry.
2. Determine the quantity and character of potentially hazardous wastes currently generated by the petroleum rerefining industry and projections of 1977 and 1983 quantities.
3. Investigate current treatment and disposal technology and present and improved technologies with acceptable health and environmental protection.

4. Estimate typical costs for three technology levels:

Level I. Most prevalent current technology
Level II. Best current technology
Level III. Technology necessary to provide adequate health and environmental protection

## 2.3 Methodology

The study has been segmented into four basic sections:

Industry Characterization (Section 3.0)
Waste Characterization (Section 4.0)
Treatment and Disposal Technology (Section 5.0)
Cost Analysis (Section 6.0)

No previous in-depth studies have been conducted of petroleum rerefining industry wastes; however, past studies sponsored by the U.S. Environmental Protection Agency have discussed these wastes.[3,4]

Each of the commercial rerefiners, as well as those former rerefiners still active in used oil recycling in some other manner, was interviewed by telephone or during plant visits. (See Appendix A) The survey form used for these interviews is shown in Appendix B.

The author developed this questionnaire to gain as much current information about the petroleum rerefining industry as possible. It is the source of much of the data presented in this report. Few rerefiners keep detailed records of waste quantities. However, cross checking using the quantity of waste oil received, rerefined oil produced and use of clay established reasonably accurate numbers. Where notable inconsistencies were indicated the author used his best judgment and information from other sources to reconcile the data. A review of the literature, private communications and the author's knowledge and experience have been employed to obtain the best possible information and data. These allowed for reasonable and viable conclusions and estimates of current and potential petroleum rerefining waste generation, treatment and disposal technology and costs, and potential environmental hazards.

## 2.4 Industry Characterization

Petroleum oil rerefining produces lubricating oil base stocks which are used in motor oils, gear oils, transmission fluids, hydraulic oils, and various industrial oil products.

The industry has 27 active rerefiners as of September 1976. This is a decline of 10% from 1975 (30 rerefiners), and an 82% reduction from 1960 (150 rerefiners).[4]

Three firms which were rerefining in 1975 are using portions of their plants for production of fuel and certain industrial oils. These plants are considered to be inactive but potentially available for rerefining. Production, approximately 44.4% of total capacity (including the six known inactive rerefiners, as well as the 27 active rerefiners), has declined from an estimated 300 million gallons in 1960 to 51 million gallons in 1975. At least eight rerefiners, with a current total production of 12 million gallons per year, are contemplating withdrawal from rerefining. However, twelve rerefiners show a production increase versus 1975, totaling 9 million gallons annually, while eleven show decreases for the same period of nearly 5 million gallons per year.

The decline in industry production and number of facilities since 1974 has been largely due to a shortage of waste oil which, with little or no processing, has been diverted to fuel use, and problems in disposing of wastes from the rerefining process.

With few exceptions, the rerefining operations are small, old and often family run. The largest plant is responsible for approximately 20% of the 1975 U.S. production, with 10 million gallons of rerefined oil. Data on plant age, size, and production are presented below.

| (Gallons) | PLANT AGE | | | EMPLOYEES | | |
|---|---|---|---|---|---|---|
| Production | <5 | 5-20 | 21-50 | <10 | 10-20 | 21-30 |
| 0-999 | 0 | 7 | 3 | 7 | 3 | 0 |
| 1000-1999 | 1 | 8 | 0 | 3 | 5 | 1 |
| 2000-3999 | 0 | 5 | 0 | 0 | 3 | 2 |
| 4000-5999 | 0 | 1 | 1 | 0 | 2 | 0 |
| 6000-10000 | 0 | 1 | 0 | 0 | 1 | 0 |

The twenty seven rerefiners are operating in 19 states. California has four facilities (15%), Texas has three (11%), and Minnesota and Wisconsin have two each (7.4%). The remaining sixteen each have only one rerefiner. The rerefineries are located in or near large cities, because of availability of the product and markets.

The more profitable rerefiners either handle a major quantity (over 30% of production) of industrial oil (including railroad oil), or engage in related activities, such as packaging and/or sales of virgin oils and anti-freeze. Fifteen percent of the rerefiners have a significant proportion (over 30%) of industrial oil production.

## 2.5 Waste Characterization

The criteria used in this study for determining the potentially hazardous nature of petroleum rerefining industry wastes are based on the proposed Interim Primary Drinking Water Standards[5] established by the U.S. Environmental Protection Agency, since leaching of toxic materials to a drinking water source is possible.

Rerefining consists of three basic processes:

1. Pretreatment, which removes unwanted constituents using heat and chemicals.
2. Distillation, usually with bleaching clay mixed

with the pretreated waste oil, which removes low boiling fractions and some of the undesirable constituents.

3. Post treatment, which removes the spent clay by filtration. It can include acid neutralization or other finishing processes or a separate clay contact treatment.

Twenty rerefiners (74.1%) use a sulfuric acid pretreatment; two (7.4%) use sodium hydroxide (caustic soda) alone or mixed with sodium silicate and surfactants. These processes produce either acid or caustic sludges. Four rerefiners (14.8%) use little or no pretreatment, but use as much as four times more than the average amount of clay during distillation. One rerefiner uses an unknown proprietary process which, purportedly, is neither acid or caustic.

All rerefiners distill by heating an oil/clay mixture to 550-650°F to remove light ends and certain constituents not removed by pretreatment. Light ends, or distillate, is similar to kerosene or home heating oil, and is largely consumed within the facility as fuel. The clay removes color bodies and other undesirable constituents not removed by pretreatment or distillation. Where only clay is used, after little or no pretreatment, most of the undesirable constituents are found in the clay rather than the pretreatment sludge. Since live steam is introduced to the oil/clay during distillation, the waste produced in this process is water containing metals, phenols, and sulfur compounds, among others.

The post treatment, currently employed by all rerefiners, removes the spent clay from the oil by filtration, and thus produces the spent clay waste.

The oil (base stock) is blended with virgin oil, if necessary for required viscosity, and additives suitable for the product end use, such as motor oil.

Acid sludge is a black, tar-like, acid material with a strong sulfuric acid odor reflecting its high acid content. It contains most of the metals, polar compounds (original additives, or compounds formed during use), and solids. Metals found in the sludge include lead, zinc, chromium, copper, iron and aluminum, among others. Since the waste oil is dehydrated before acid pretreatment, it contains little or no water.

Sludge from caustic (sodium hydroxide) pretreatment may contain as much as 20% water as produced, but is usually disposed in an essentially dry state, since the water separates in storage and is removed before disposal. It is somewhat emulsifiable and can be made more fluid by neutralizing with acid and/or diluting with waste oil or rerefinery distillate. The pH ranges from alkaline (pH 10.0) to close to neutral, or approximately pH 7. It contains the same metals as acid sludge, as well as the original additives and compounds, such as oxidized petroleum fractions, formed during use. There is some evidence to indicate that there is a lower degree of aromatic hydrocarbon removal.[6]

Spent clay, a grey-tan powder in its original state, is black and oil compacted, ranging from very oily and greasy to slightly oily after contact with the oil during distillation. Common and low cost solvents can remove much of the adsorbed oil and other contaminants. The spent clay contains lead and other heavy metals, phenols, oils, and other compounds.

Solid waste from process water treatment is negligible, and is included in the sludge. No separate record of this sludge is kept by rerefiners.

There are four sources of wastewater in the rerefining operation:

1. Water contained in the raw waste which settles during storage.
2. Ground water run-off, which may contain oil from spills and leakage.
3. Process cooling water.
4. Steam stripping water, which is that resulting from live steam introduced during distillation.

The most significant of these, from the potentially hazardous waste standpoint, is the steam stripping process water which contains small, but troublesome, quantities of lead, zinc, and phenols, for example. It also contains quantities of hexane solubles (oils, polymers and polar compounds) considerably higher than levels specified by the U.S. Environmental Protection Agency.

The 27 rerefiners using acid, caustic, or other pretreatments, produced in their wastes the following 1975 estimated amounts of some of the substances considered to be hazardous in the environment.

| Hazardous Substances | ACID SLUDGE Generation (Metric tons/yr) | ACID SLUDGE Typical Analysis (PPM) | CAUSTIC SLUDGE Generation (Metric tons/yr) | CAUSTIC SLUDGE Typical Analysis (PPM) |
|---|---|---|---|---|
| Sulfuric Acid | 9,913.0 | 27.0 (%) | 0 | 0 (%) |
| Lead * | 660.9 | 19,000 | 163.8 | 27,500 |
| Arsenic | 1.5 | 45 | 0.4 | 45 |
| Zinc | 69.4 | 3,100 | 13.3 | 1,500 |
| Cadmium | 0.3 | 9 | 0.1 | 7.5 |
| Chromium | 1.3 | 28 | 0.3 | 18 |
| Oil, Polymers, Polar Compounds & Asphalt | 11,896.0 | 57.3 (%) | 2,699 | 33.0 (%) |

* It should be noted that the lead content of waste oil is being reduced with the increased use of low and no-lead gasoline.

No specific investigations have been made of the potential carcinogenic properties of rerefining wastes by EPA, National Institute of Occupational Safety & Health (NIOSH), or Occupational Safety & Health Administration (OSHA). However, it has been stated that virgin lubricating oil contains polynuclear aromatics which have been determined to be carcinogenic.[7] Used oils show a higher percentage of such constituents than virgin oils.[7] Since the rerefining process removes many of these constituents from the waste oil,[8] it is logical to assume that the rerefining wastes are potentially carcinogenic. Further waste oil analyses, including polynuclear aromatics, by National Bureau of Standards (NBS), as mandated by the Energy Conservation Act of 1975, should increase knowledge in this area and provide a data base for a more complete investigation. It may also offer further data supporting this assumption regarding the carcinogenic properties of rerefining wastes.

Other potentially carcinogenic agents may also be present. Recent findings indicate high levels of nitrosamines in metalworking fluids. These materials may well become constituents of industrial oily waste and, hence, constituents of the waste oil. It is also indicated that these carcinogenic compounds could be found in used motor oils since both nitrogen and amine compounds are found in motor oils, with possible formation of nitrosamines.[9] Further research needs to be done in this area. There may well be other toxicological, carcinogenic and mutagenic hazards not previously addressed.

Sludges derived from rerefining of industrial oils, including diesel engine oils, vary, depending on the source. The lead content of used diesel engine oil is very low, approximately 13% of that found in used gasoline oils. Metalworking oils may contain substantial amounts of iron, aluminum, copper, tin, and chromium, as well as fatty oils, soaps and emulsifiers, corrosion and rust inhibitors, sulfur, chlorine, and phosphorus compounds.

The hazardous properties of spent clay are of a considerably lower order of magnitude. There has been much less investigation of spent clay than of acid sludge. However, lead content in spent clay is reported as only 8% of that found in acid sludge.[10] Excluding four rerefiners using clay only or other processes with no acid or caustic pretreatment, the amount of lead in the clay is estimated at 76.8 metric tons annually. Rerefiners using the clay-only process contribute an estimated 139.8 metric tons of lead.

The other metals, such as zinc, removed by the clay-only process are present in the clay in proportion equal to that found in the waste oil.[11] The undesirable polar compounds and polymers will also be found in the spent clay.

The rerefining industry reports production of 81 million gallons of rerefined oil for 1975 with the following waste generation:

| Waste Type | Metric tons/yr (dry weight) |
|---|---|
| Acid sludge | 33,045 |
| Caustic & other sludge | 8,180 * |
| Spent clay | 15,700 |

* Caustic sludge contains water as produced but is usually substantially water-free at disposal since the water separates in storage.

It is difficult to project the waste stream quantities for 1977 and 1983, because of the steady decline of the rerefining industry since 1960, and because of the uncertainty of its survival. Five current major factors indicate continuing decline. These are as follows:

1. Waste disposal problems, such as unavailability of disposal facilities or increased costs of transportation and/or disposal.
2. High waste oil feed stock prices due to use of unprocessed oil as fuel.
3. Reduced virgin oil prices.
4. Age of company owners with little successor management.
5. Financial inability to make potential process changes for efficiency, and environmentally adequate handling of waste requiring large capital investment.

However, four factors could provide a favorable climate for increased production of rerefined oils in 1977 and 1983. These are:

1. Governmental action in control of burning of raw waste oil.
2. Favorable legislative action on re-imposed excise taxes on virgin oils.
3. Removal of the Federal Trade Commission labelling requirement for rerefined oils.
4. Improved market prices for lubricating oils.

While a decline in the number of currently active rerefiners is probable, new and larger rerefineries with improved technology could be in operation in the near future.

With the above factors in mind, the following rerefined oil production and waste quantities are projected for 1977 and 1983.

| Year | Production Gallons ($10^6$) | Increase over 1975 Gallons ($10^6$) | Sludge generation Metric tons ($10^3$ dry wgt) | Increase over 1975 Metric tons ($10^3$ dry wgt) |
|---|---|---|---|---|
| 1977 | 68.9 | 18.0 (36%) | 54.2 | 12.9 (31%) |
| 1983 | 183.3 | 132.6 (35%) | 91.8 | 50.4 (122%) |

| Year | Production Gallons ($10^6$) | Clay generation Metric tons ($10^3$ dry wgt) | Increase over 1975 Metric tons ($10^3$ dry wgt) |
|---|---|---|---|
| 1977 | 68.9 | 20.0 | 4.4 (28%) |
| 1983 | 183.3 | 52.5 | 36.8 (234%) |

It is estimated that the use of low lead and unleaded gasoline will reduce the lead content of sludge and spent clay by 70% by 1983. The lead concentration is expected to be approximately 2,000 PPM in waste motor oil, 6,000 PPM in rerefining sludge generated by current processes, and 8,800 PPM in sludge or bottoms generated by improved technology.

It is also possible to project a near complete disappearance of the rerefining industry by 1983 if no governmental action is taken to eliminate uncontrolled burning of raw waste oil and road oiling, and if current tax and labelling restrictions on waste oil continued. Waste oil generated and recovered would then be used as fuel, with or without processing.

## 2.8 Treatment and Disposal Technology

The levels of treatment and disposal technology for the petroleum rerefining industry are defined as follows:

| | |
|---|---|
| Level I | The use of off-site or on-site landfills without treatment of wastes such as acid neutralization or use of fixative materials. |
| Level II | The use of landfills with some form of waste treatment to reduce leaching of hazardous substances. |
| Level III | The use of either chemically secure landfills with or without treatment of waste; or use of sanitary landfills after environmentally adequate treatment of waste to prevent leaching of potentially hazardous substances. |

Sixteen, or 80%, of the rerefiners having acid sludge use Level I disposal practices, which are disposed in environmentally inadequate landfills, on-site landfills, or use on roads. Thirteen rerefiners use commercial or municipal landfills, two use on-site landfills, and one spreads the sludge on roads. Off-site landfill and road oiling disposal account for 74.2% (24,525 metric tons) of the total acid sludge generated. There are 2,870 metric tons, or approximately 9% of the total acid sludge generated, disposed in on-site landfills.

Level II technology, the best disposal practice currently employed, is practiced by four rerefiners (20%) which utilize acid pretreatment. This technology includes treatment of wastes by mixing with a neutralizing agent, and/or fixative materials. These rerefiners generate a total of 5,850 metric tons, or approximately 18% of the total acid sludge produced annually. Three rerefiners use off-site landfills and one treats and disposes of the waste on-site.

Total caustic and "other" sludge generated totals 8,180 metric tons. About 1,440 metric tons, or 17.6% of this sludge, is applied on roads. An equal quantity is mixed with waste oil and heavy virgin fuel and burned as a fuel. The remainder, 5,300 metric tons, or 64.8% of the total caustic and "other" sludge generated, is used as an asphalt extender and plasticizer. These three methods, respectively, dispose of 12.8%, 3.5%, and 3.5% of total sludge generated. Therefore, if it is assumed that the sludge which is used as fuel and that used in asphalt products are products of rerefining rather than waste, then the 1,440 metric tons used for road oiling becomes the total quantity of caustic and other sludge requiring disposal.

Road oiling is considered to be a Level I technology disposal method.

Only four rerefiners utilize sludge treatment methods which qualify as best current practice (Level II). Current leaching tests on one neutralizing and fixating process are currently being conducted under EPA sponsorship. Should these tests show satisfactory results, the processes, and others similar, would qualify as Level III technology when done prior to landfilling.

Road oiling, using either acid or caustic sludge, is environmentally unacceptable unless it can be demonstrated that suitable methods for fixation of hazardous substances can be, or are, possible.

The rerefining industry generated 15,700 metric tons of spent clay in 1975. Twenty five, or 92.6%, of all rerefiners use Level I technology for disposal of 14,235 metric tons per year. Nineteen use off-site landfills (11,930 tons), two dispose of the clay via use on roads (1,097 tons), and four use on-site landfills (1,208 tons).

Two rerefiners use Level II technology for disposal of spent clay. That is, the clay is mixed with a fixative and deposited in a landfill. Here again, the environmental adequacy of these methods must be determined by leaching tests.

At this time, the only Level III technology is deposition of the sludge and spent clay wastes in secure landfills from which hazardous substances cannot leach.

The following is a summary of petroleum rerefining waste types and quantities vs. disposal technology levels in 1975:

Waste Disposal Technology Level
metric tons/yr (dry wgt)

| Waste Type | Level I | Level II | Level III |
|---|---|---|---|
| Acid sludge | 27,195 | 5,850 | 0 |
| Caustic, other sludge* | 1,440 | 0 | 0 |
| Spent clay | 14,235 | 1,485 | 0 |

*A significant amount of caustic and other sludge generated is reused as either a fuel or a product.

## 2.7 Cost Analysis

Petroleum rerefining waste disposal costs vary widely. Since the major proportion of the waste is disposed in off-site landfills, transportation cost is a significant factor.

Few rerefiners separate contributory waste disposal costs, such as, plant labor, equipment amortization, and percentage of overhead. Landfill charges and transportation costs are available, and other costs have been imputed with the agreement of the individual rerefiner.

The following summary shows the range of costs and average cost per metric ton (dry weight) of each waste type and the total current industry costs for waste disposal for each technology level.

Petroleum Rerefining Waste Disposal Costs
($/Metric ton, dry weight)

| Technology Levels | Sludge Acid & Caustic | Average | Clay | Average | Total Industry Cost | Estimated Industry Sales * $10^3$ |
|---|---|---|---|---|---|---|
| I | $3-31.00 | $10.74 | $1-15.00 | $6.20 | $534,489 | |
| II | 5-15.00 | 7.83 | 3.50-15. | 6.68 | 73,209 | |
| III | 0 | 0 | 0 | 0 | 0 | |
| | | | | Total | $607,698 | 22,950 |

* Author's estimate based on bulk price per gallon of $0.45 for rerefined oil without additives.

## 3.0 Characterization of the Petroleum Rerefining Industry

### 3.1 Introduction

The petroleum rerefining industry is composed of small operations with a maximum of 35 and an average of 11 employees. Seventy percent of the production of the industry is less than 3 million gallons per year. In most cases, the equipment has been designed and fabricated by the operator, often from second hand material. Despite the fact that the facilities do not compare in the technical sophistication or efficiency associated with the typical manufacturing process industries, the product (lubricating oil) is, or can be, of high quality. Traditionally, marginal profits have prevented capital investment on a large scale.

The major volume of waste oil processed is provided by used motor oil sources, i.e., service stations, garages, car dealers, and truck, bus, and automobile fleets (See Table 1). The oil products composing the wastes are automotive lubricants, motor oils, gear oils, and transmission fluids. Some firms process small amounts of industrial oils from manufacturing plants. Four rerefiners, in industrial areas, handle relatively substantial quantities (30% or more) of the industrial oils and produce cutting and hydraulic oils. Several factors, such as unfavorable governmental action, waste disposal problems, high feed stock cost, and marketing problems, have caused a continuing decline of rerefined oil production.

## 3.2 History of Waste Oil Rerefining

Recycling of automotive waste oils has been practiced since 1915. The subject was addressed by W. H. Herschel and A. H. Anderson of the National Bureau of Standards in 1922.[12] Production of rerefined oils increased steadily until 1960 when the industry produced an estimated 300 million gallons. Use of rerefined oils by aircraft industry was a positive factor in aiding the growth of the industry. Military aircraft used substantial quantities of rerefined oils before, during, and after World War II with a peak usage of 1,147,810 gallons in 1949.[13] Increasing use of jet engine aircraft using synthetic lubricants virtually

## TABLE 1

## WASTE OIL GENERATION 1975, 1971
(gallons $10^6$)

| | Sales | | Waste * Oil Factor | Oil | |
|---|---|---|---|---|---|
| | 1975 | 1971 | | 1975 | 1971 |
| **Automotive Lube Oils** | | | | | |
| Service Stations | 239 | 270 | .63 | 150 | 170 |
| Garages, Auto Supply Stores | 90 | 60 | .63 | 57 | 38 |
| New car dealers | 103 | 102 | .90 | 93 | 92 |
| Retail sales for commercial engines | 95 | 90 | .63 | 60 | 57 |
| Auto fleet & other lube oil uses | 151 | 136 | .50 | 75 | 68 |
| Factory fills (auto & farm equipment) | 54 | 60 | .90 | 49 | 54 |
| Discount stores | 250 | 168 | .22 | 55 | 37 |
| Commercial engine fleets | 225 | 200 | .50 | 112 | 100 |
| Total | 1,207 | 1,086 | | 651 | 616 |
| **Industrial & Aviation Lube Oils** | | | | | |
| Hydraulic & circulating system oils | 314 | 325 | .42 | 132 | 137 |
| Metal working oils | 145 | 150 | .70 | 101 | 105 |
| Railroad engine oils | 58 | 60 | .53 | 31 | 32 |
| Gas engine oils | 60 | 62 | .90 | 54 | 56 |
| Aviation & other | 147 | 137 | .50 | 73 | 64 |
| Total | 724 | 734 | | 391 | 394 |
| **Other Industrial Oils** | | | | | |
| Process Oils | 340 | 310 | .10 | 34 | 31 |
| Electrical Oils | 62 | 57 | .90 | 56 | 51 |
| Refrigeration Oils | 11 | 10 | .50 | 6 | 5 |
| Total | 413 | 377 | | 96 | 87 |
| Lube Oils Purchased by U.S. | 32 | 37 | .50 | 16 | 18 |
| GRAND TOTALS | 2,376 | 2,234 | | 1,154 | 1,115 |

* Waste oil factor indicates the percentage of oil available for recycling as opposed to that lost in use or discarded to the environment.

** National estimates by the American Petroleum Institute and other Petroleum Industry sources range from 400 to 750 for 1971. No estimates from such sources are available for 1975.

Source: See Appendix

eliminated this market. Military oil specifications since 1964 have banned the use of rerefined oils in government owned and operated vehicles.

The decline of the industry is the result of the following factors:

1. Reduced yield and higher operating costs due to increased additive content.
2. Aggressive and negative marketing activity and governmental lobbying by virgin oil producers.
3. Governmental action in removing excise taxes from virgin oils in the Excise Tax Reduction Bill of 1965, which eliminated the competitive price advantage of non-taxed rerefined oil.
4. The Federal Trade Commission (FTC) labelling requirement. (Trade Regulation Rule relating to Deceptive Advertising and Labelling of Previously Used Lubricating Oil; effective September 1, 1965) - requiring the legend "Made from Previously Used Oil" on the container.
5. Problems in disposal of wastes, such as State, municipal and commercial landfill operators' refusal to accept rerefining wastes or sharply increased charges for those that are accepted. In several cases, rerefiners have been forced

to use landfills as far distant as 450 miles with subsequent increased transportation charges.

6. An increase in waste oil feed stock prices by 400-600 percent from 1974. It is estimated that over 90% of the recoverable waste oil is being used as fuel with little or no processing to remove sulfur, metals, and other contaminants.

7. Current reduced prices on virgin lubricating oils; i.e., from approximately $0.50/gallon to as low as $0.34/gallon.

At this time there are twenty-seven rerefiners operating with an annual production of approximately 80.8 million gallons vs. 150 rerefiners with an annual production of 300 million gallons in 1960.

### 3.3 Overview of Reclaiming, Reprocessing, and Rerefining Industries

Waste automotive oils contain water, solids, and additives, such as detergents, blended with the original oil; compounds, such as petroleum oxidates and resins, formed during use; and metals, such as lead, iron, and copper from gasoline and engine parts wear. It is necessary to remove all of these materials to produce a high quality lubricating oil base stock.

Waste industrial oils also contain extraneous materials, although they differ. Fatty oils, sulfur and chlorine compounds, rust and oxidation inhibitors, and soaps and emulsifiers, as well as metals, are found in industrial waste oils.[14]

### 3.3.1 Used Oil Recycling Processes

Three processes of oil recycling can be defined; 1) reclaiming, 2) reprocessing, and 3) rerefining. (See Table 3)

Reclaiming removes water, solids, and a degree of polar and other compounds. Heat (100°-150°F), gravity, or centrifugal separation, screening, coarse filtration, and possible use of demulsifiers are employed. This simple process produces cleaner oils primarily for fuel use. Some of the oil is used as a parting agent on concrete forms.

Reprocessing uses higher temperatures (150°-210°F) with chemicals such as sodium hydroxide (caustic soda), sodium silicate, and, possibly, special surfactants to assist in demulsification and solids settling. The higher temperature also removes gasoline and other low boiling hydrocarbons. This process removes the solids, water, a large percentage of original additives, and compounds formed or introduced during use. Products are clean fuels, parting agents, and

## TABLE 9

## WASTE LUBE OIL RECYCLING METHODS

### RECLAIMING

| | |
|---|---|
| Removes | Water, solids |
| Process | Heat 100°-180°F.<br>Separatory screening<br>Demulsification<br>Gravity settling or centrifugation |
| Products | Fuel<br>Parting agents, e.g., concrete forms |

### REPROCESSING

| | |
|---|---|
| Removes | Water, solids<br>Additives blended with original oil<br>Compounds formed during use |
| Process | Heat 180°-200°F.<br>Chemical treatment, acid, caustic, sodium silicate<br>Surfactants (demulsification, solids settling)<br>Gravity settling or centrifugation<br>Separatory screening<br>Filtration |
| Products | Fuel<br>Non-critical lubricants<br>Parting agents |

### REREFINING

| | |
|---|---|
| Removes | Water, solids<br>Original additives<br>Compounds formed during use<br>Light ends (low boiling fractions)<br>Color bodies and soluble high boiling compounds |
| Process | Chemical pretreatment (similar to reprocessing)<br>Distillation 550°-650°F.<br>Clay contact<br>Filtration |
| Products | Distillate fuel<br>Lubricating oils<br>Motor oils<br>Hydraulic oils<br>Machining oils<br>Process oils |

certain non-critical lubricants. There is little quality control practiced in reprocessing operations.

Rerefining usually consists of a pretreatment similar to, but more intensive than that used in reprocessing; higher temperatures ($550^0$-$650^0$F) is required for distillation and clay contact followed by filtration (post treatment). The process produces lubricating oil base stocks and a distillate fuel fraction.

There is little information available on reclaiming and reprocessing activities and volume. In general, these are small operations employing simple technology with somewhat less than impressive equipment. A very inexact estimate supposes 70 reprocessors in the U.S. with an annual production of 100 to 200 million gallons. It is reasonable to assume a 10% sludge and tank bottoms generation or 40,000 to 80,000 metric tons (dry weight).

### 3.4 Sources and Quantities of Waste Oils

Waste oils used by rerefiners, and most of that handled by reprocessors, are generated by lubricating oil users. These are reported by the U.S. Bureau of Census as automotive, aviation, industrial lubricating, and industrial oils. Table 3 shows a total increase in sales of lubricating and industrial oils and greases

## TABLE 3

## SALES OF LUBRICATING AND INDUSTRIAL OILS AND GREASES[1]

1967, 1969, 1971, 1973 and 1975

| | YEAR | | | | |
|---|---|---|---|---|---|
| Product | 1975 | 1973 | 1971 | 1969 | 1967 |
| | | | ($10^6$ gal.) | | |
| Oils, lubricating & industrial: (gal. $10^6$) | | | | | |
| Automotive ---- | 1,250.7 | 1,272.5 | 1,126.6 | 1,147.3 | 1,132.6 |
| Aviation ------ | 20.8 | 21.9 | 22.0 | 28.5 | 37.4 |
| Total | 1,271.5 | 1,294.4 | 1,148.6 | 1,175.8 | 1,170.0 |
| Industrial: | | | | | |
| Lubricating ---- | 996.3 | 1,134.2 | 1,027.0 | 1,087.5 | 985.6 |
| Other ---------- | 590.3 | 699.7 | 538.4 | 533.1 | 464.7 |
| Total | 1,586.6 | 1,833.9 | 1,565.4 | 1,620.6 | 1,450.3 |

of 283.5 million gallons between 1965 and 1975. The 1965 sales was 2,574.6 million compared with 2,858.1 million in 1975. It is noteworthy that industrial oil sales rose at a greater rate than automotive oils, i.e., 191.4 million gallons vs. 92.1 million gallons. This indicates longer oil change periods which, in turn, has decreased the yields and increased processing problems of rerefiners. The Waste Oil Study, Report to Congress, April 1974, estimates generation of 1.1 billion gallons per year of recoverable waste oils. The 1975 generation of waste oil has been estimated using the same waste oil factors. Table 1 shows sources and quantities of waste oil generated in 1972 and 1975.

It is estimated that recoverable waste automotive lube oils totaled 616 million gallons in 1972. Industrial and aviation oils, other industrial oils, and U.S. lube oil purchases account for 394 million, 87 million, and 16 million gallons per year respectively. The 1975 generation of recoverable waste oil is estimated at 1,260 million gallons. Automotive lube oils accounted for 673 million gallons while industrial oils, aviation oils, and other industrial oils generated 571 million gallons. U.S. Government agencies contributed 16 million gallons of used oil.[4]

## 3.5 Rerefined Oil Products

Products in the automotive market include motor oils, transmission fluids, and railroad car journal oils. The major industrial oils are hydraulic oils, machine oils, and metal cutting oils. The latter usually do not require the degree of intensive pretreatment and high temperature clay in-situ distillation necessary for hydraulic and motor oils. Only four rerefiners process comparatively high percentages of industrial oils. They are located in the industrial areas of the midwest.

All products, unless sold as blending stock oils to others, contain additives such as detergents and dispersants, oxidation inhibitors, and pour point depressants. Industrial oils contain such additives as fatty oils, sulfur and chlorine compounds, and rust and oxidation inhibitors to meet specifications and operating requirements (Refer to Appendix C).

## 3.6 Industry Characterization

The twenty-seven active rerefiners are located in nine of the ten EPA Regions. There is no rerefiner in Region I (New England). Sixteen are found in Regions IV, V and VI, with four in Region IX, two each in Regions II and III, and one each in Regions VII, VIII and X. Only nineteen of the states have one or more rerefiners located within their boundaries. California has four; Texas has three; Minnesota and Wisconsin each have two. The remaining sixteen rerefiners are located in sixteen states. Table 4 shows the geographical distribution by EPA Regions as well as the range of the number of employees and the age range of the plants.

Appendix A lists the twenty-seven active rerefiners as well as six inactive rerefiners (those who discontinued rerefining, but use their plants for production of fuels and some industrial oils). The rerefining capacity is therefore, inactive and not fully utilized and, if conditions warranted, could be reactivated for lube oil rerefining.

The number of rerefinery employees range from four to twenty-five with two plants having five or fewer employees. The other twenty-five rerefiners employ from six to twenty-five employees.

Every attempt was made to show only employees directly involved in the refining operation to give a more comparative picture. Thus, employees involved in packaging, i.e., filling of one quart to five gallon containers, were not included since many rerefiners do not package their own products. In most cases, those who do operate packaging equipment also do custom work for other firms. Several rerefiners also distribute virgin oil products.

Several rerefiners preferred to report lower ages than

### TABLE 4

(1975)

REREFINERIES

### DISTRIBUTION OF PLANTS BY EPA REGIONS, EMPLOYEES AND AGE

| EPA Region | # of Plants | Employees * |  |  | Plant Age (yrs) |  |  |
|---|---|---|---|---|---|---|---|
|  |  | 0-5 | 6-25 | 26-50 | 0-5 | 6-30 | 30-50 |
| I | 0 | - | - | - | - | - | - |
| II | 2 |  | 2 |  |  | 2 |  |
| III | 2 |  | 2 |  |  | 2 |  |
| IV | 5 |  | 5 |  |  | 3 |  |
| V | 7 | 1 | 6 |  |  | 4 | 3 |
| VI | 4 | 1 | 3 |  | 1 | 2 | 1 |
| VII | 1 |  | 1 |  |  | 1 |  |
| VIII | 1 |  | 1 |  |  |  | 1 |
| IX | 4 |  | 4 |  |  | 4 |  |
| X | 1 |  | 1 |  |  | 1 |  |

* Only those in rerefining

that which would be shown if the inception date were shown. The rationale for this is that improvements or updated replacements and capacity increases have, in effect, established newer plants. The data reflect this preference, but it should be noted that several of the rerefiners commenced operations at much earlier dates than those shown. Plant age, as reported, varies from three years to forty-six years.

Table 5 shows the industry capacity, processes used, and product distribution by EPA Regions. The 1975 production was 48% of reported capacity. Some plants operate on a seven-day/twenty-four hour basis while others vary from five days/one shift per day to five days/three shifts per day.

Two factors account for the current lower than capacity operations of the rerefining industry. First, inadequate and high priced waste oil feed stock, and second, a softening market with subsequent reduction in prices for virgin oils. A great percentage, possibly as high as 60% in 1975, of the estimated recoverable waste oil is being used as fuel with collectors, reclaimers, and reprocessors receiving from $0.15/gallons for unprocessed waste oil to $0.28 for reprocessed oil. In late 1973 rerefiners were paying $0.03 to $0.05 per gallon for waste oil delivered to their plants. During the oil shortage period of 1974 prices on virgin oils more than doubled, allowing

### TABLE 5

(1975)

### REREFINERIES

### DISTRIBUTION OF PLANTS BY PRODUCTION QUANTITIES, PROCESSES, AND PRODUCTS PRODUCED

| EPA Region | Production ($10^3$ gallons) | | Processes | | | | Products | | |
|---|---|---|---|---|---|---|---|---|---|
| | Lube Capacity | Lube Production | Acid | Caustic | Solvent | Others | Auto | Industrial | Fuel |
| I | 0 | 0 | 0 | 0 | 0 | 0 | - | - | - |
| II | 5,600 | 4,200 | 1 | 1 | | | X | X | X |
| III | 13,000 | 4,300 | | | 1 | 1 | X | X | X |
| IV | 15,050 | 6,125 | 4 | | | 1 | X | X | X |
| V | 26,750 | 19,435 | 5 | | | 1 | X | X | X |
| VI | 21,300 | 9,400 | 2 | | | 2 | X | X | |
| VII | 4,800 | 1,500 | 1 | | | | X | | |
| VIII | 1,500 | 1,150 | 1 | | | | X | X | X |
| IX | 8,800 | 3,320 | 4 | | | | X | X | X |
| X | 600 | 425 | 1 | | | | X | | X |
| Total | 110,900 * | 50,965 | 19 | 1 | 1 | 5 | | | |

* With inactive or fuel-only plants total capacity = 114,600.

the rerefiners to raise their prices on base rerefined oils (oils less additives) from an average of $0.22/gallon to $0.50/gallon, and, in some cases higher for bulk loads. However, prices for similar virgin oils dropped to around $0.42/gallon and in August 1976 were reported to be as low as $0.34/gallon. The result is that the rerefiners are caught in a financial squeeze which has drastically reduced, if not eliminated, profits.

Twenty rerefiners (74%) use the acid pretreatment process, two (7.4%) use caustic (sodium hydroxide) and five use clay-only or other processes. One of the latter uses an undisclosed proprietary process and is categorized in the "other" process type.

All twenty-seven of the rerefiners produce automotive oils; twenty-five, in seven EPA Regions, produce some quantity of industrial oils, although only four (15%) process substantial quantities (more than 30% of the production). All rerefiners report sales of fuels, usually the excess of plant requirements. Most of the fuel sold is that produced by the distillation process, but an unknown amount may be sales of either raw waste oil or that which results from reprocessing.

The industry can be characterized as one with small operations as measured by the number of employees, the volume of production, and the sales volume. The largest has a total number of employees of twenty-five (no packaging facilities and only two waste oil collection trucks) and, with 10 million gallons/year production, accounts for nearly 20% of the total industry production. Two other rerefiners produce 20% of the total. Five rerefiners account for over 27% of the total industry production; thus, eight, or 30% of the rerefiners, account for over 66% of the total annual U.S. production. Ten rerefiners (37%) produce less than 10% of total annual production. The rerefineries, with few exceptions, are owner operated facilities. The industry has attracted few younger and technically qualified persons.

Profits have traditionally been marginal since prices are keyed to those charged for virgin oils. The experience of 1975 is typical in that virgin oil prices are being reduced due to oversupply. What is not typical is the competition for, and increased prices of, the raw waste oil diverted to fuels. The costs of environmental controls and waste disposal are adding significantly to the operating costs.

The annual production per employee ratio reflects production volume and, usually, reflects full scale operation (seven twenty-four hour days per week) vs. five days per week operation. The ratio ranges from 28,000 gallons per year to 800,000 gallons per year.

Table 6 lists active rerefiners in order of production volume and the percentage of total industry production. The capacity and percentage of industry capacity is also shown for each rerefiner.

The rerefineries, with few exceptions, have been

## TABLE 6
(1975)
## PETROLEUM REREFINERS PRODUCTION AND CAPACITY VS INDUSTRY TOTALS
($10^3$ gallons/yr)

| Rerefiner | Production | % of Total Industry Production | Capacity | % of Total Industry Capacity |
|---|---|---|---|---|
| 1 | 10,000 | 19.6 | 12,000 | 12.3 |
| 2 | 5,500 | 10.8 | 7,500 | 8.0 |
| 3 | 4,200 | 8.2 | 6,000 | 6.2 |
| 4 | 3,500 | 6.9 | 10,000 | 10.3 |
| 5 | 3,500 | 6.9 | 4,000 | 4.1 |
| 6 | 2,500 | 4.9 | 5,000 | 5.1 |
| 7 | 2,400 | 4.7 | 3,600 | 3.7 |
| 8 | 2,100 | 4.1 | 7,200 | 7.4 |
| 9 | 1,800 | 3.5 | 2,000 | 2.0 |
| 10 | 1,800 | 3.5 | 3,600 | 3.7 |
| 11 | 1,600 | 3.1 | 2,500 | 2.6 |
| 12 | 1,500 | 2.9 | 4,800 | 4.9 |
| 13 | 1,200 | 2.3 | 3,000 | 3.1 |
| 14 | 1,200 | 2.3 | 2,500 | 2.6 |
| 15 | 1,150 | 2.2 | 1,500 | 1.5 |
| 16 | 1,000 | 1.9 | 2,000 | 2.0 |
| 17 | 1,000 | 1.9 | 3,800 | 3.9 |
| 18 | 850 | 1.6 | 2,000 | 2.0 |
| 19 | 800 | 1.6 | 3,000 | 3.1 |
| 20 | 700 | 1.4 | 2,800 | 2.9 |
| 21 | 650 | 1.3 | 1,500 | 1.5 |
| 22 | 425 | 0.8 | 600 | 0.6 |
| 23 | 420 | 0.8 | 2,500 | 2.6 |
| 24 | 360 | 0.7 | 1,800 | 1.8 |
| 25 | 285 | 0.6 | 1,000 | 1.0 |
| 26 | 225 | 0.5 | 750 | 0.8 |
| 27 | 200 | 0.4 | 250 | 0.3 |
| Total | 50,865 | 100.0 | 97,200 | 100.0 |

owner-built in an incremental fashion, often with second-hand equipment installed and modified by rerefinery employees. While much ingenuity and, often, innovative methods have been employed, the typical rerefinery does not have the efficiency factor common to the chemical or petroleum process industries.

## 4.0 Waste Characterization

### 4.1 Introduction

Rerefining generates three waste streams - sludge, spent clay, and process water.

Wastes from rerefining are similar to those produced by virgin oil acid/clay refining. However, the acid sludge from virgin oil refining did not contain the metals, particularly lead, found in rerefining sludge. This prevents rerefiners from using a high temperature acid recovery system with subsequent use of the acidless low-metal content sludge as fuel.

Spent clay, currently used in oil refining, is reclaimed by burning the petroleum constituents adsorbed by the clay.

No economically or technically feasible method has been discovered for reclaiming the acid sludge produced by 74% of the rerefining industry. The use of caustic pretreatment sludge as an asphalt extender/plasticizer and the absence of acid and other more desirable characteristics point toward reclamation possibilities for this sludge. The volume of spent clay produced by a rerefiner is currently too small to permit economical reclamation and reuse of the spent clay, although those using a clay-only process could achieve quantities sufficient to amortize the capital investment.

## 4.2 Rerefining Process Description

Figure 1 shows a petroleum rerefining general flow diagram and average mass balance. The three major process areas are shown: pretreatment, distillation, and post-treatment. The figure is applicable to any rerefining process.

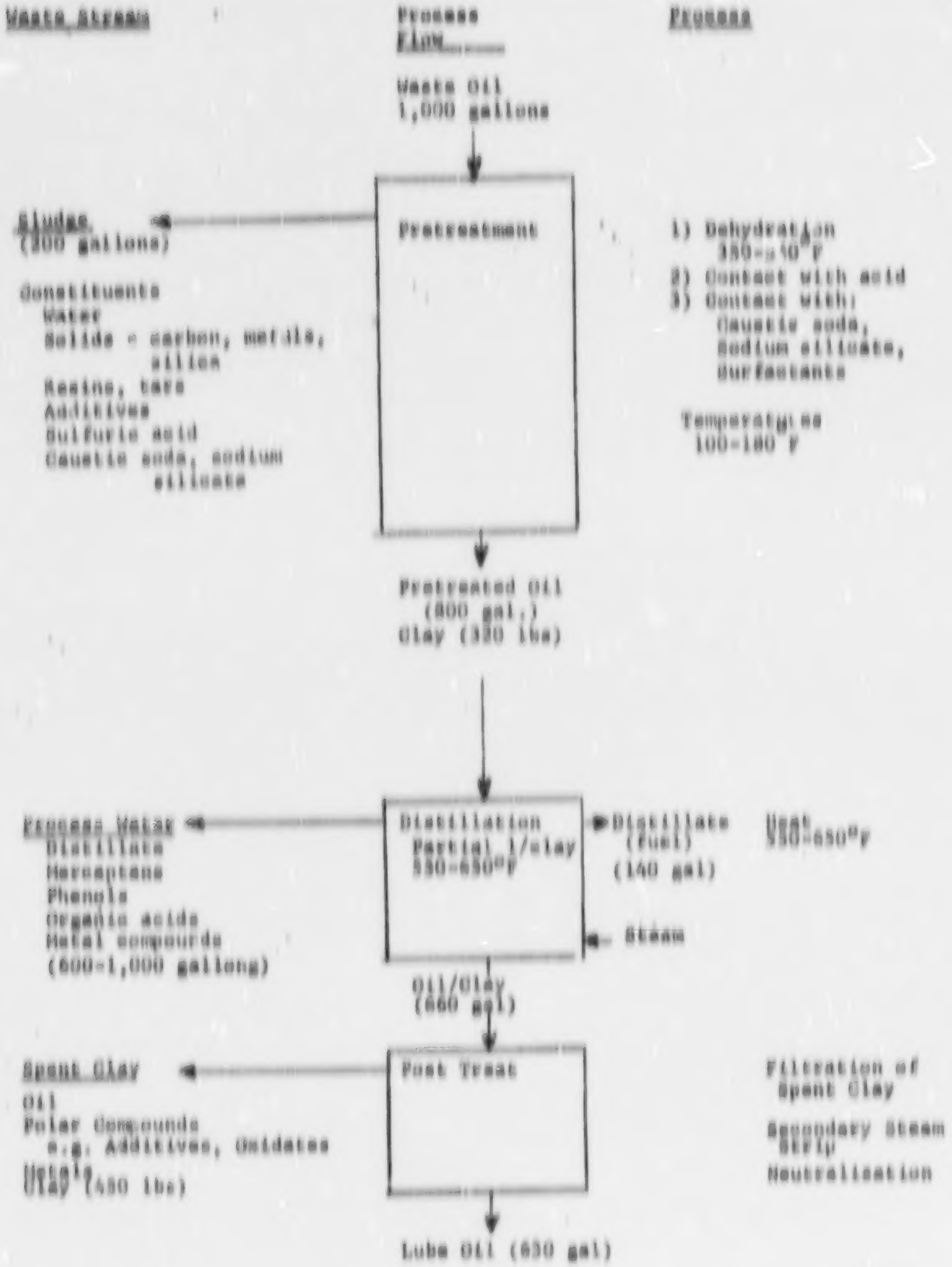
### 4.2.1 Pretreatment

Pretreatment currently practiced includes mixing of waste oil with sulfuric acid or sodium hydroxide. The latter process may also include use of sodium silicate and/or surfactants. Patents have been issued for processes which extract the sludge constituents with solvents. It is understood that other proprietary methods using neither acid, caustic, nor solvent are in the developmental stage. None of these processes are being used commercially at this time.

Acid pretreatment has three steps; dehydration of the waste oil; mixing of acid and oil at $90^{\circ}F$ to $110^{\circ}F$; and settling and removal of sludge. Caustic pretreatment, practiced by two [illegible]finers varies somewhat in details but basically

FIGURE 1

FLOW DIAGRAM - CURRENT WASTE OIL REREFINING PRACTICE


Waste Stream
Process Flow
Process
Waste Oil
1,000 gallons
Sludge
(200 gallons)
Constituents
Water
Solids - carbon, metals, silica
Resins, tars
Additives
Sulfuric acid
Caustic soda, sodium silicate
Pretreatment
1) Dehydration 350-550°F
2) Contact with acid
3) Contact with: Caustic soda, Sodium silicate, Surfactants
Temperatures 100-180°F
Pretreated Oil (800 gal.)
Clay (320 lbs)
Process Water
Distillate
Mercaptans
Phenols
Organic acids
Metal compounds
(600-1,000 gallons)
Distillation
Partial 1/clay
550-650°F
Distillate (Fuel)
(140 gal)
Heat
550-650°F
Steam
Oil/Clay
(660 gal)
Spent Clay
Oil
Polar Compounds
e.g. Additives, Oxidates
Metals
Clay (450 lbs)
Post Treat
Filtration of Spent Clay
Secondary Steam Strip
Neutralization
Lube Oil (630 gal)

consists of mixing raw (not completely dehydrated) waste oil and sodium hydroxide, or a mixture of sodium hydroxide (caustic soda) and sodium silicate. Surfactants to improve settling rate and quality may be used. The sludges from each process contain most of the same undesirable constituents of the waste oil but are quite different in physical characteristics. The caustic sludge, of course, does not contain acid.

### 4.2.2 Distillation

Today's commercial rerefiners use a partial distillation of the pretreated oil with clay in-situ (0.3 to 0.5 lbs/gal). The oil is heated to 550°F to 650°F. Distillate, or light ends (low boiling fractions), are removed as a vapor and condensed. The distillate is similar to kerosene and contains some undesirable constituents which were not removed by pretreatment.[10] Live steam is introduced to the oil/clay mixture to produce better clay contact and to assist in removing light ends and constituents, such as mercaptans, which have an affinity for water. The distillate/steam vapor is condensed and the resulting mixture separates readily yielding distillate and steam stripping process water. Ammonia, sodium hydroxide, sodium carbonate, and/or organic amine compounds are added to the vapor stream prior to condensation to reduce equipment corrosion, improve odor, and produce a better distillate.

The clay-only process eliminates the pretreatment step. The raw waste oil with approximately 1.8 lbs/gallon of clay is distilled directly at the usual 550°F to 650°F temperatures. All of the undesirable constituents which usually form the sludge are adsorbed by the clay.

Total vacuum distillation (to date only conducted in laboratory or pilot plant operations) uses temperatures in the 945°F range with high vacuum.[18] This vaporizes the lube fraction, which is the residual of partial distillation, and leaves bottoms (sludge) as a residual.

### 4.2.3 Post Treatment

Post treatment in current rerefining practice consists of removal of spent clay from the oil/clay residual after partial distillation. Other forms of post treatment are secondary neutralization of the oil and secondary steam stripping to improve the odor and neutralization number by removal of trace acidic compounds.

Research has been done on hydrotreating of the lube fraction from total vacuum distillation with good laboratory results.[18] Most virgin lube oils today are contacted with hydrogen (hydrotreating) to remove sulfur, nitrogen, and other unwanted constituents, rather than clay contact. This would eliminate the spent clay disposal problem. However, a much larger volume of through-put, than any rerefiner now has, would be necessary to make the process economically viable.

Hydrotreating is not now being used commercially, although one company is installing equipment for this process method as well as for total vacuum distillation.

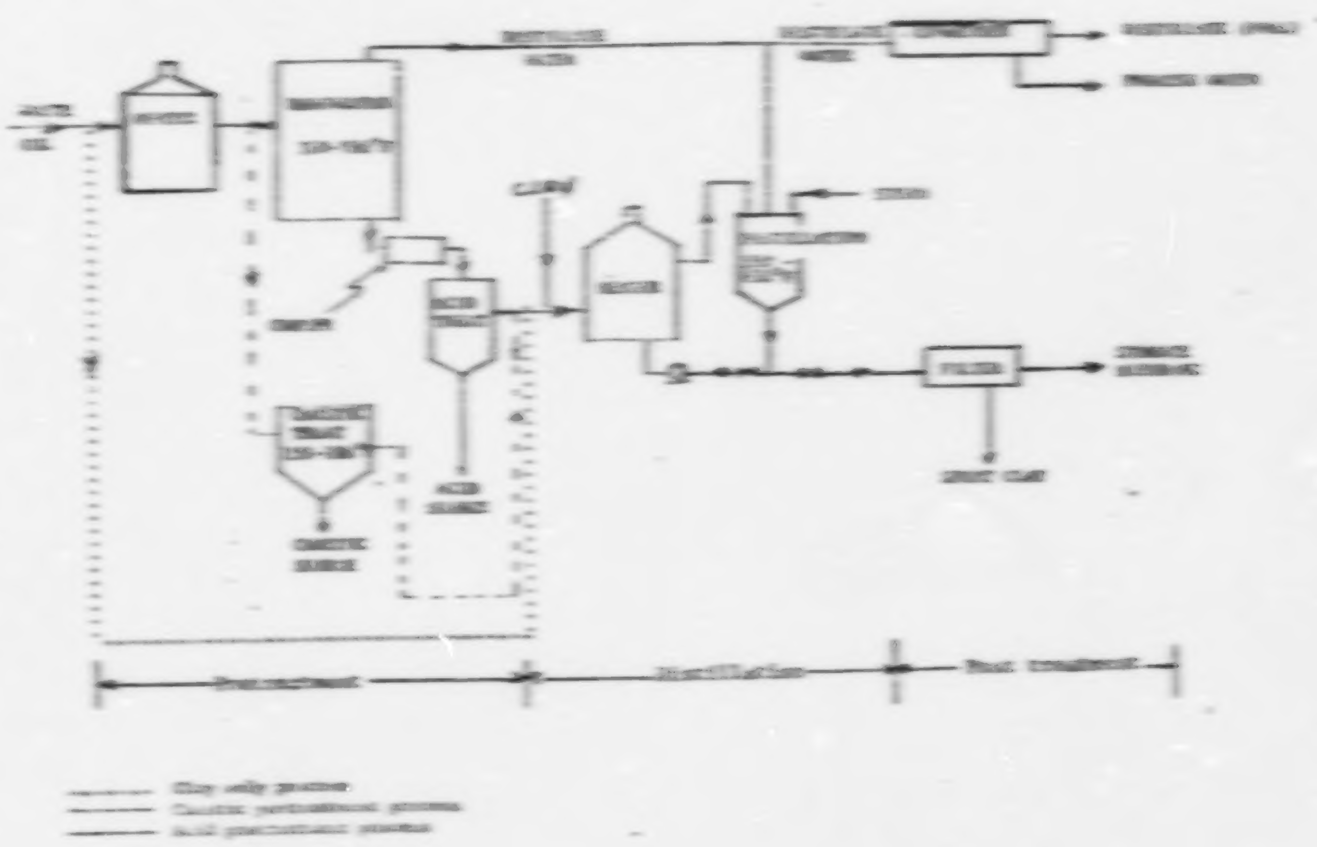
### 4.2.4 General Processing

Figure 2 is a three part flow diagram applicable to acid, caustic, or the clay-only process. The pretreatment section shows a heater utilized to raise the temperature of the waste oil to 140°F-200°F for caustic pretreatment (dash line) or 350°F-550°F for dehydration prior to acid pretreatment (solid line). After either caustic or acid pretreatment and removal of the sludge the oil in either case is mixed with clay and moves to a second heater to raise the oil temperature to 550°F-650°F for removal of light ends by distillation.

In the clay-only process (dotted line) waste oil bypasses pretreatment, clay is added and the oil/clay mixture is heated to approximately 650°F.

FIGURE 2

FLOW DIAGRAM - CURRENT PETROLEUM REREFINING PROCESSES - CLAY-ONLY; ACID PRETREATMENT; CAUSTIC PRETREATMENT


WASTE OIL
ACID TREAT
ACID SLUDGE
CAUSTIC TREAT
CAUSTIC SLUDGE
CLAY
STEAM
DISTILLATION
FILTER
SPENT CLAY
Pretreatment
Distillation
Post treatment
Clay only process
Caustic pretreatment process
Acid pretreatment process

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The clay addition step on the flow diagram for the three processes is substantially the same and one solid line is shown.

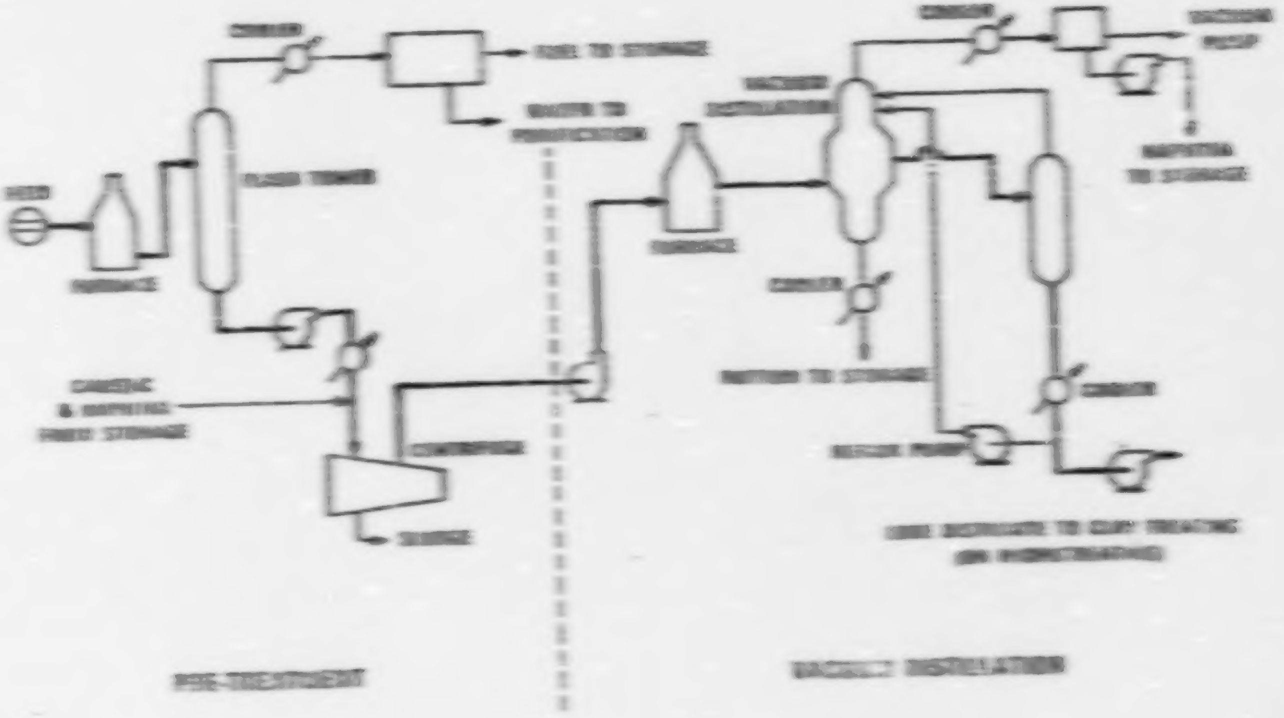
Figure 3 shows a flow diagram of a caustic/solvent/clay process. The solvent is plant produced distillate and acts primarily as a viscosity reducer rather than an extractant. In other respects the process is similar to that used by other rerefiners.

Since waste motor oils contain from 3% to 18% bottoms, sediment, and water (BS&W) and have an original oil additive content of 8% to 15%, the average sludge loss is approximately 20%. Yield of lube oil is between 55% and 65% of the untreated waste oil. The distillate, or light ends, yield is approximately 15%-25%. Appendix C shows the composition and function of some lubricating oil additives which, with compounds fotmed during use and metals from engine wear, become the rerefining sludge.

Some rerefiners, using acid pretreatment, dehydrate the oil at temperatures in the 500°F-550°F range. This, not only removes the water in the raw waste oil, but, also, removes most of the light ends (distillate). This reduces the amount of acid required for pretreatment but does not appreciably alter the nature of the sludge.

FIGURE 3[4]

REREFINING BY CAUSTIC/SOLVENT/CLAY PROCESS


FEED
FURNACE
FLASH TOWER
CONDSR
FUEL TO STORAGE
WATER TO PURIFICATION
CAUSTIC
& NAPHTHA
FROM STORAGE
CENTRIFUGE
SLUDGE
FURNACE
VACUUM
DISTILLATION
CONDSR
VACUUM
PUMP
NAPHTHA
TO STORAGE
COOLER
BOTTOM TO STORAGE
COOLER
REFLUX PUMP
LUBE DISTILLATE TO CLAY TREATING
(OR HYDROTREATING)
PRE-TREATMENT
VACUUM DISTILLATION

## 4.3 Criteria for Determination of Potentially Hazardous Wastes

Leaching of potentially hazardous constituents of rerefining wastes can contaminate drinking water sources as well as affect recreational waters. Therefore, the Interim Primary Drinking Water Standards established March 1976 by the U.S. Environmental Protection Agency[5] have been selected as a criteria for determination of petroleum rerefining hazardous wastes. The author has also included hexane solubles (oil, polymers and polar compounds) and phenol standards established by the Water Quality Standards of the State of Illinois,[10] since the Federal Standards are not specific for these constituents. Since hazardous constituents are contained in the raw waste oil the adverse effects of contamination of ground water must also be considered.

Table 7 lists the drinking water standards established by the U.S. Environmental Protection Agency and State of Illinois.

The highest concentration of undesirable contaminants in acid sludge is, of course, the oil (hexane soluble or equivalent) at over 57% including polymers, polar compounds, and asphaltenes, as well as petroleum oil (See Table 8). Acid content is reported to range from 27.0% to 47.5%.[8]

The metals found in acid sludge in the highest average

## TABLE 7

## CRITERIA FOR DETERMINING HAZARDOUS WASTES FROM PETROLEUM REREFINING

A. Interim Primary Drinking Water Standards Maximum Contaminant Levels for Inorganic Chemicals[5]

| Contaminant | Level (Mg/L) |
|---|---|
| Arsenic | 0.05 |
| Barium | 1.0 |
| Cadmium | 0.010 |
| Chromium | 0.05 |
| Cyanide | 0.2 |
| Lead | 0.05 |
| Mercury | 0.002 |
| Nitrate (as N) | 10.0 |
| Selenium | 0.01 |
| Silver | 0.05 |

B. Derived from State of Illinois Water Quality Standards[16]

| Constituent | Level (Mg/L) |
|---|---|
| BOD & Suspended Solids, general | 30 |
| Oil (hexane solubles or equivalent | 15.0 |
| pH | 5-10 |
| Phenols | 0.3 |
| Total suspended solids | 15.0 |

concentration are lead, 20,000 PPM, calcium, 1,000 PPM, zinc, 1,500 PPM, and phosphorus, 1,100 PPM; materials such as chromium, arsenic, cadmium, and even mercury have been reported in addition to iron, aluminum, manganese, nickel, and others.

Caustic sludge does not contain sulfuric acid, but does contain the polymers, polar compounds, asphaltenes, and petroleum oil as well as metals in the same concentration range.

In the rerefining process which does not pretreat the oil, but uses much larger amounts of activated clay, the sludge constituents are adsorbed by the clay.

Potentially carcinogenic materials such as polynuclear aromatics (PNA's) and nitrosamines, in rerefining wastes have been given little attention. Neither the Occupational Safety and Health Agency (OSHA) nor the National Institute for Occupational Safety and Health (NIOSH) have conducted specific investigations of this area.

However, it is possible to draw certain conclusions from published data. Irwin and Liroff[7] discuss and cite references pertaining to the potential toxicity and carcinogenicity of improperly disposed used oil. They state that polycyclical aromatic hydrocarbons are carcinogenic and that the content of these compounds are higher in used oil than in virgin oil.

Putscher[8] shows a total content of 57.3% of lube oil (naphthenes, paraffins, aromatics), polymers, other polar compounds, and asphaltenes, and other residues in acid sludge (See Table 8). Some of these are polycyclical aromatics, for example. Whisman, et.al[16] have demonstrated that used motor oils contain 12.8% monoaromatics, 3.82% diaromatics, and 81.57% polyaromatics. Irwin and Liroff also mention that cadmium found in petroleum rerefining sludge is suspected of having carcinogenic effects.[7] They also state that carcinogens found in oil are known to affect DNA. While the authors state that the DNA experiments did not consider used oils, data from other sources indicate the need for further study in this area.

Petroleum rerefining removes and concentrates many of the constituents in the oil which could be considered carcinogenic. Therefore, more detailed study of this potential hazard should be investigated.

## 4.4 Waste Analysis Data

Each of the process steps produces waste streams. Pretreatment sludge quantities include tank bottoms which contain mainly water and solids. The water may contain phenols and other water soluble or dispersible compounds. Solids include metals such as lead and zinc. Dehydration,as a pretreatment step,produces a process water containing phenols and mercaptans, among others, particularly when higher temperatures and steam

## TABLE 8

## ACID SLUDGE ANALYSIS[a]

| Soluble in Water | Wt. % |
|---|---|
| Ash | 4.2 |
| Acid ($H_2SO_4$) | 27.0 |
| **Insoluble in Water** | |
| Ash | 8.4 |
| Acids | 1.6 |
| Volatiles (150°C, @ 1 mm Hg) | 0.8 |
| Lube Oil (naphthenes, paraffins, aromatics) | 15.5 |
| Polymers | 18.6 |
| Other Polar Compounds | 1.8 |
| Asphaltenes and Other Residues | 21.4 |
| | 99.3 |

are used to remove light ends before the major distillation step. Unfortunately, there is limited data available pertaining to this process waste water.

Table 9 shows analytical data on two acid pretreatment sludges. One acid sludge analysis is that from processing of diesel lube oil, the other from oils used in gasoline engines. Variances indicate the differences in additives used in each type of oil and the use of non-leaded fuel in diesel engines.

Table 10 not only shows the high density (10 lbs/gal) of acid sludge but its high viscosity. As a comparison, an SAE 30 motor oil would have a viscosity at 100°F of 250 to 300 contrasted with the sludge viscosity of 475,000 @ 105°F. Table 11 shows an analysis of sludge derived from a caustic/silicate pretreatment. The 27,500 parts per million (PPM) of lead is in a similar range to that found in acid sludge (20,000 PPM). Differences in the data can be explained by differences in sampling, raw waste oil makeup, and analytical procedures. The higher silicon content reflects the use of sodium silicate. The BTU/lb value indicates a substantial heat value approximately equal to distillate fuels used in homes and smaller commercial boilers.

Little detailed analytical work has been performed on petroleum rerefining spent clay. Table 12 shows an oil content of 19%. This is composed of polar materials,

## TABLE 9

## ACID SLUDGE ANALYSES
## COMPOSITE

| | Weight % | | |
|---|---|---|---|
| | Diesel[4] | Stock[4] | Stock[17] |
| % Acid | 47.5 | 40.8 | NA |
| Ash Sulfate | 4.45 | 11.26 | NA |
| Sulfur | 14.9 | 14.1 | NA |
| Sulfur calculated from % acid assuming $H_2SO_4$ | 15.5 | 13.3 | NA |
| **Elemental Analysis, ppm** | | | |
| Cu | 40 | 40 | 190 |
| Al | 40 | 140 | 560 |
| Fe | 800 | 1,100 | 3,200 |
| Si | 800 | 1,400 | NA |
| Pb | 1,000 | 20,000 | 10,000 |
| Ag | 14 | 0 | 0.8 |
| Zn | 200 | 2,100 | 2,100 |
| Ba | 400 | 1,300 | 740 |
| Cr | 100 | 50 | 28 |
| Ca | 12,000 | 6,400 | NA |
| Na | 200 | 4,000 | NA |
| P | 1,000 | 4,300 | 1,700 |
| B | 40 | 50 | 19 |
| Ni | 10 | 30 | 8 |
| Sn | 35 | 30 | NA |
| Mg | 70 | 1,000 | NA |
| Cd | 9 | NA | NA |
| Mo | 18 | NA | NA |
| Mn | 65 | NA | NA |
| As | 45 | NA | NA |
| Be | 0.1 | NA | NA |
| Co | 0.8 | NA | NA |
| Sr | 2.7 | NA | NA |
| V | 18 | NA | NA |

NA = Not available

## TABLE 10

## PHYSICAL CHARACTERISTICS OF ACID SLUDGE [4]

| Physical Characteristics | |
|---|---|
| Density, lbs/gal. | 10.0 |
| Viscosity, SSU | |
| 75°F. | 4,000,000 |
| 105°F. | 487,000 |
| 125°F. | 150,000 |
| pH | 0.1 |

## TABLE 11

## ANALYSIS OF REREFINING CAUSTIC/SILICATE SLUDGE [18]
## 1973

| Element | PPM |
|---|---|
| Fe | 330 |
| Pb | 27,800 |
| Cu | 48 |
| Cr | 18 |
| Al | 24 |
| Ni | 1 |
| Ag | 1 |
| Sn | 70 |
| Si | 6,250 |
| B | 10 |
| Na | 1,000 |
| P | 1,100 |
| Zn | 1,300 |
| Ca | 1,000 |
| Ba | 3,000 |
| S | 0.14% |
| BTU/lb | 18,333 |

## TABLE 12

## ANALYSIS OF PETROLEUM REREFINING SPENT CONTACT CLAYS [4]

| Physical Characteristic | Average | Range |
|---|---|---|
| BTU/lb. | 6000 | 1000 - 9250 |
| Particle size, sieve no. | 170 | 30 - 300 |
| Volatile solids, wt. % | 14 | 0 - 55 |
| Ash, wt. % | 83 | 0 - 99.8 |
| Oil, wt. % | 19 | 1 - 45 |
| pH | 5.6 | 3.5 - 7.5 |
| Water, wt. % | 8 | 0 - 36 |

not removed by pretreatment, as well as lube oil.

Table 13 gives results of more recent work (1975) sponsored by EPA.[10] It compares five samples of acid sludge and one of caustic sludge to an acid sludge generated by laboratory bench scale acid pretreatment rerefining of waste oil supplied by the rerefiner using a caustic pretreatment. The only metal analyzed was lead and it is noteworthy that the laboratory acid pretreatment reduced the lead content of the oil from 0.66% (6600 PPM) to 0.05% (500 PPM). Table 14, (derived from the same program) shows lead content of 5.6% of that found in the original oil (0.66%) despite losses in analytical procedure. With the exception of the small amount of lead found in the distillate it is most likely that 95% of the lead was removed by the pretreatment.

Steam was not used during distillation, which probably would show a somewhat higher percentage of lead in the distillate.

It is noteworthy that the Diamond Head waste oil shows a lead content of 0.66%. Earlier reports indicated an average of approximately 1.0% (10,000 PPM) in waste motor oils (crankcase oil). The reduction in lead indicates the increased use of low lead and no lead gasolines.

Table 15 provides analytical data on spent clay from

## TABLE 14

## LEAD MATERIAL BALANCE FOR WASTE CRANKCASE OIL ACID/CLAY REREFINING[10]

| | Raw Waste Oil | Acid Sludge | Distillate | Clay | Rerefined Oil | Total |
|---|---|---|---|---|---|---|
| Pb% Total | 100.0 * | 71.2 | 0.02 | 5.63 | 1.22 | 77.07 |
| Pb Content (lbs) per 100 gal. raw waste oil ** | 5.016 | 3.57 | 0.001 | 0.28 | 0.011 | 3.87 |

* Lead content of raw waste oil equals 0.66% (6,600 PPM)

** Raw waste oil averages 7.6 lbs/gal.

Note: Twenty three (23%) Pb loss due to unremovable resins in distillation flask and volutilization during analytical ashing. Best estimate is that greatest loss occurred in sludge rather than clay. Lead in distillate/neutral and rerefined oil should be reasonably accurate and indicative of commercial practice.

## TABLE 13

## LABORATORY ANALYSIS OF ACID AND CAUSTIC SLUDGE[19]

| | [illegible] acid sludge | [illegible] acid sludge | [illegible] acid sludge | Diamond Head caustic sludge | [illegible] acid sludge | Bay Side acid sludge | Diamond Head untreated waste oil | Acid sludge from Diamond Head waste oil | Acid treated Diamond Head waste oil |
|---|---|---|---|---|---|---|---|---|---|
| Density, g/cc | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| Density, lb/gal | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| Gravity, API 60F | - | - | - | - | - | - | [illegible] | - | [illegible] |
| Neutralization number, mg KOH | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| Neutralization number, mg HCl | - | - | - | [illegible] | - | - | - | - | - |
| Ash content, % | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| Carbon content, % | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| Hydrogen content, % | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| Oxygen content, % | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| Sulfur content, % | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| Nitrogen content, % | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| Lead content, % | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| Sulfate content, % | - | [illegible] | [illegible] | - | - | - | [illegible] | [illegible] | [illegible] |
| Oil content, % | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | 97.2 |
| Pentane insoluble resins content, %[a] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| Polymer content, % | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| Combined acid (or base) and nonextractable organics content, % | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| Viscosity, SUS at 100°F | - | - | - | - | - | - | [illegible] | - | [illegible] |
| Viscosity, Cs at 100°F | - | - | - | - | - | - | [illegible] | - | [illegible] |
| Viscosity, SUS at 210°F | - | - | - | - | - | - | [illegible] | - | [illegible] |
| Viscosity, Cs at 210°F | - | - | - | - | - | - | [illegible] | - | [illegible] |
| Viscosity index | - | - | - | - | - | - | [illegible] | - | [illegible] |

[a] May be referred to as asphalt content.

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## TABLE 18

## ANALYSIS OF SPENT CLAY FROM CLAY-ONLY REREFINING PROCESS

| Physical/Chemical Characteristics | Quantity |
|---|---|
| BTU/lb | 7452 |
| ABD (Apparent Bulk Density) | 34 lbs/ft$^3$ |
| Benzene Soluble | 32.4% |
| Loss on ignition 850°C | 46.8% |
| Loss of ignition 850°C (after benzene solubles removal) | 22.3% |

| Metals | % | PPM |
|---|---|---|
| Aluminum | 2.34 | 23,400 |
| Barium | 0.42 | 4,200 |
| Calcium | 0.40 | 4,000 |
| Chromium | 0,013 | 1,300 |
| Copper | 0,012 | 1,200 |
| Iron | 0.85 | 8,500 |
| Lead | 3.95 | 39,500 |
| Magnesium | 1.02 | 10,200 |
| Manganese | 0,012 | 1,200 |
| Nickel | 0,006 | 60 |
| Silicon | 15.88 | 158,800 |
| Tin | 0.001 | 10 |
| Zinc | 0.43 | 4,300 |

a clay-only process and verifies the contention that the process is effective in removing unwanted constituents (sludge) from the waste oil. The benzene solubles are additives that are compounds formed during use. The high metals content, such as aluminum, magnesium, manganese, and silicon, among others, reflects those naturally occurring in the clay. The lead content includes that usually found in the sludge and the clay from processes using pretreatment.

## 4.9 Waste Stream Data

Petroleum oil rerefining generates three major waste streams: sludge, spent clay, and process water, all of which contain hazardous substances.

Sludge is predominantly composed of the product of acid or caustic pretreatment. However, it may contain storage tank bottoms, the interface invert emulsion found in the condensed light ends/stripping steam separation, and waste water treatment sludge. A major portion of the lead found in waste motor oil is trapped in the sludge. Other metals will be found in quantities proportionate to their concentration in the raw waste oil. Based on designation of hazardous substances as established by the Environmental Protection Agency,[19] potentially hazardous levels are identified for the following materials which may be found in rerefining wastes:

Sulfuric acid
Ammonia
Arsenic compounds*
Cadmium compounds
Chromium compounds
Copper compounds
Cresol
Iron compounds
Lead compounds
Mercury compounds
Naphthene compounds
Phosphorus compounds
Nickel compounds
Zinc compounds
Oils

* Not all arsenic and other listed compounds are hazardous, but since we do not know the form of arsenic compounds, these and others are listed as possibilities for further study.

If acid is not used in pretreatment, sludge (or bottoms), which must be generated by any rerefining method, constitutes a hazardous waste based on heavy metals concentration and presence of aromatic hydrocarbons.

Sludge from sulfuric acid pretreatment is a black tar-like material. Its highly viscous nature, plus the fact that it is not soluble in common or inexpensive solvents, makes separation of the acid and solids difficult. Even when the acid is removed, there appears to be no economically feasible method of resource recovery for the material. The portion remaining after acid and solvent removal contains approximately one third each of petroleum oil, polymers, and asphaltenes.[8] However, another study of rerefining acid sludge indicates that it cannot be used as an asphalt replacement, at least for road building.[80]

Table 16 shows an analysis of ten used lubricating oils. Variations in lead, for example, are probably explained by sampling procedure, water and solvent dilution,

# TABLE 16

## METALS AND PHOSPHORUS CONTENT OF 10 USED LUBRICATING OILS[21]

| Sample Number | Ba | Ca | Mg | Na | P | Zn | Al | Cr | Cu | Fe | K | Mo | Ni | Pb | Si | Sn | V |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1477 | 430 | 1,461 | 225 | 115 | 671 | 990 | 13 | 7 | 22 | 119 | 41 | 3 | 0 | 6,485 | 43 | NA[2] | 0 |
| 1478 | 485 | 1,317 | 165 | 72 | 622 | 918 | 14 | 8 | 43 | 203 | 79 | 4 | 5 | 7,385 | 25 | NA | 0 |
| 1479 | 428 | 1,072 | 259 | 95 | 815 | 780 | 13 | 5 | 41 | 150 | 24 | 2 | 0 | 6,560 | 39 | NA | 0 |
| 1480 | 260 | 1,431 | 227 | 100 | 764 | 860 | 10 | 7 | 41 | 129 | 20 | 9 | 1 | 4,890 | 38 | NA | 0 |
| 1481 | 203 | 1,358 | 458 | 102 | 1,015 | 1,233 | 12 | 8 | 38 | 232 | 33 | 3 | 0 | 10,410 | 36 | NA | 7 |
| 1482 | 144 | 1,267 | 261 | 89 | 708 | 910 | 7 | 6 | 37 | 116 | 25 | 2 | 0 | 4,365 | 27 | NA | 0 |
| 1483 | 278 | 1,008 | 297 | 357 | 778 | 1,040 | 21 | 24 | 37 | 655 | 83 | 8 | 0 | 8,005 | 67 | NA | 0 |
| 1484 | 520 | 1,170 | 182 | 107 | 674 | 600 | 11 | 8 | 18 | 179 | 57 | 4 | 2 | 4,560 | 37 | NA | 0 |
| 1485 | 333 | 1,704 | 229 | 85 | 986 | 1,140 | 13 | 8 | 41 | 173 | 37 | 3 | 2 | 7,680 | 32 | NA | 0 |
| 1486 | 319 | 1,425 | 375 | 125 | 961 | 990 | 20 | 11 | 31 | 214 | 36 | 4 | 2 | 7,570 | 51 | NA | 0 |

varying ratios of oil from gasoline engines, and the low lead content used in diesel engines. These 1975 analyses show the effect of decreased lead content in low-leaded gasolines.

Caustic pretreatment sludge is a black viscous material which varies from free flowing to weakly gelatinous and from neutral to alkaline. It may contain up to 30% water, most of which settles out, particularly if a small amount of acid is used to neutralize the excess sodium hydroxide and break the gel structure. This sludge is soluble in common solvents including refinery produced distillates and waste oil itself. It is also emulsifiable.

These sludges have been grouped under the column heading, "caustic sludge", since the solvent used in the one pretreatment is used for dilution before centrifuging rather than as an extractive solvent. The "caustic/silicate" designation is used to differentiate it from the "caustic/solvent" and to account for a larger percentage of silicon, which was found on analysis. The other metals are found in quantities similar to those in acid treated sludge. It should be noted that differences in various metals between acid and caustic pretreatment analytical data used in this report are not particularly significant since sampling procedures vary, and the makeup of the waste oil varies to some extent based on area and source, e.g., diesel engine oil vs. gasoline engine oil. Diesel engine oil has very little lead since unleaded fuel is used.

Spent clay is a black, oil-compacted material with varying percentages of oil. These variations are due more to filtration practice and equipment than to basic process methods. There is very little analytical data available for spent clay. In that used after pretreatment Sahagian reports that 8.8% of the lead in the waste oil is found in spent clay.[10] It is probable that other metals are present in the same proportion as found in the raw waste oil although the reactivity factors of some metals or compounds must be considered. The oil portion, reported to be 1-48% of the clay[4] probably contains a major portion of polymers and other polar compounds not removed at the pretreatment step. Before storage, the clay contains no water. However, the usual storage practice in open containers or in piles allows for water addition.

The clay-only process, which uses approximately four times the amount of clay than that used with pretreated oil, contains all of the sludge constituents of the waste oil. If the waste oil contains 0.88% lead, it would be expected that there is 3.83% lead in the clay when used at a dosage of 1.5 pounds per gallon. Analyses done in 1975 by one rerefiner are shown in Table 15. There was 3.95% lead shown, which indicates that the waste oil had approximately 0.9% lead which is within expected limits. Leaching tests[11] show the following percentage examples of some metals leached from spent and unused clays based on amounts released:

| Metals | From Spent Clay | From Fresh Clay |
|---|---|---|
| Iron | 1.43 % | 1.08 % |
| Barium | 0.215 | 0.263 |
| Calcium | 19.0 | 11.4 |
| Magnesium | 29.7 | 12.6 |
| Zinc | 0.217 | 0.025 |

Analytical data on steam stripping process water is also limited. Table 17 lists hexane solubles, total solids, and metals found in untreated and treated process water. The treatment process includes neutralization and coagulation. The water treatment processes a water acceptable for municipal sewage systems. However, the lead content (4 PPM) of the untreated water must be compared with the Federal Interim Drinking Standards of 0.05 PPM. Hexane solubles of 200 PPM and BOD of 220 on treated water can be compared with the State of Illinois Water Quality Standards of 15.0 mg/L (milligrams per liter = PPM) and 30 mg/L. This indicates a need for concern in the case of most rerefiners who do not treat their water to any great degree.

The second water generated that is of potential hazard is the run-off containing oil or sludge resulting from spills or leaks and possible leaching of spent clay in temporary storage areas. The oil portion of this water will, of course, contain the potentially hazardous constituents found in raw waste oil, sludge, and clay.

## TABLE 17

## PROCESS WATER (STEAM STRIPPING)
## FROM THE ACID/CLAY OIL REREFINING PROCESS - 1976[22]

| Constituent | Untreated (PPM | Treated (PPM |
|---|---|---|
| Hexane | 200 | 25 |
| Total Solids | NA | 20 |
| BOD | NA | 220 |
| Sodium | 0 | 75 |
| Zinc | 3 | 0 |
| Copper | 0 | 0 |
| Aluminum | 0 | 2 |
| Barium | 0 | 0 |
| Nickel | 0 | 0 |
| Chromium | 0 | 0 |
| Calcium | 150 | 75 |
| Iron | 13 | 1 |
| Silicon | 8 | 1 |
| Tin | 0 | 0 |
| Lead | 4 | 0 |
| Phosphorus | 0 | 0 |
| Boron | 2 | 1 |
| Magnesium | 37 | 23 |
| Vanadium | 0 | 0 |
| Molybdenum | 0 | 0 |
| Manganese | 0 | 0 |
| Cadmium | 0 | 0 |
| Titanium | 0 | 0 |
| Mercury | NA | 0,0002 |

Spectographic Results

## 4.6 Waste Quantities for 1975

Table 18 shows the total quantity of acid sludge, caustic, other sludge, and clay generated by the rerefining industry in 1975, distributed by EPA Regions. Sludges which are reclaimed are included in the totals of waste generated, but subtracted to show the quantities that must be disposed of by rerefiners. All quantities are shown as dry weight even though the caustic sludge may contain small amounts of water after settling or water removal on-site by the rerefiners. Neither the acid sludge nor the spent clay contain water except the negligible amount from rain or air borne moisture during storage in open containers. Most of the water originally present in the caustic sludge separates by gravity leaving only a negligible amount in the sludge. No determination of this quantity has been made for this report.

Table 19 shows total estimated quantities of metals, acid, oil, polymers, and polar compounds considered to be hazardous substances generated by the industry in 1975. The largest quantity of potentially hazardous waste is that under "oils", 17,736 metric tons. This material is a mixture of petroleum oils, additives originally blended with the oil, and compounds formed during use. The latter category includes oxidized and polymerized petroleum compounds as well as reaction products resulting from gasoline blow-by. Acid, the second highest constituent at 9,913 metric tons is the

## TABLE 16

## ANNUAL GENERATION OF SLUDGE AND SPENT CLAY FROM PETROLEUM RE-REFINING IN 1975 BY EPA REGIONS

(metric tons/year - dry weight)

| EPA Regions | SLUDGE Acid | % Total Sludge | SLUDGE Caustic, Other | % Total Sludge | SPENT CLAY | % Total |
|---|---|---|---|---|---|---|
| I | 0 | | 0 | | 0 | |
| II | 2,340 | 5.7 | 2,880 | 7.0 | 1,368 | 8.7 |
| III | 0 | | 5,300 | 12.8 | 745 | 4.7 |
| IV | 5,395 | 13.1 | 0 | | 2,976 | 19.0 |
| V | 11,713 | 28.4 | 0 | | 5,427 | 34.6 |
| VI | 8,675 | 21.0 | 0 | | 3,657 | 23.3 |
| VII | 720 | 1.7 | 0 | | 180 | 1.1 |
| VIII | 600 | 1.5 | 0 | | 600 | 3.8 |
| IX | 2,692 | 6.5 | 0 | | 657 | 4.2 |
| X | 910 | 2.2 | 0 | | 90 | 0.6 |
| Total | 33,045 | 80.1 | 8,180 | 19.8 | 15,700 | 100.00 |
| Total Sludge | 41,225 | | | | | |
| Total Clay | 15,700 | | | | | |
| Total Waste | 56,925 | | | | | |

## TABLE 19

### TOTAL POTENTIALLY HAZARDOUS SUBSTANCES GENERATED BY U.S. PETROLEUM REREFINING INDUSTRY-1975
(metric tons/year - dry weight)

| EPA Regions | Acid | Oils* | As | Ba | Cd | Cr | Cu | Pb | Zn |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Constituents | | | | | |
| I | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| II | 713.7 | 2,068.3 | 0.12 | 5.2 | 0.02 | 0.26 | 0.38 | 112.2 | 4.7 |
| III | 0 | 1,698.0 | 0.37 | 5.3 | 0.06 | 0.26 | 1.0 | 110.2 | 17.2 |
| IV | 1,615.8 | 2,337.2 | 0.24 | 5.6 | 0.05 | 0.22 | 0.65 | 168.3 | 11.3 |
| V | 3,509.2 | 5,302.1 | 0.53 | 11.7 | 0.12 | 0.46 | 1.41 | 278.1 | 24.6 |
| VI | 2,597.1 | 3,854.4 | 0.39 | 8.7 | 0.08 | 0.34 | 1.06 | 238.5 | 18.2 |
| VII | 216.1 | 295.1 | 0.03 | 0.7 | 0.01 | 0.03 | 0.09 | 15.8 | 1.5 |
| VIII | 178.6 | 336.0 | 0.03 | 0.6 | 0.01 | 0.03 | 0.07 | 15.3 | 1.3 |
| IX | 812.6 | 1,100.4 | 0.12 | 2.7 | 0.03 | 0.11 | 0.32 | 57.2 | 5.6 |
| X | 267.7 | 345.0 | 0.04 | 0.9 | 0.01 | 0.04 | 0.11 | 18.3 | 1.9 |
| Total | 9,913.0 | 17,736.5 | 1.87 | 41.2 | 0.39 | 1.38 | 4.97 | 1,013.8 | 86.3 |

*Oils: includes polymers, polar compounds, asphalt and petroleum oils.

unreacted sulfuric acid used in pretreatment. As would be expected, lead at 1,013 metric tons is the metal found in the largest quantity.

Table 20 shows a distribution by EPA Regions of most of the metals, those considered hazardous as well as others not considered hazardous. Acid, oils, polymers, polar compounds, and asphalt found in acid sludge are also listed. Table 21 shows metals and oils found in caustic and other sludges. The caustic sludge, of course, contains no acid and usually has very little unreacted sodium hydroxide or sodium silicate since any excess would be removed from the sludge with the water separated during storage. The less viscous and tarry consistency of the caustic sludge, as compared with acid sludge, also permits better separation of petroleum oil. Therefore, the caustic sludge contains an average of 33 percent oil as opposed to 36 percent in acid sludge. These metals and other substances are not distributed by EPA Regions since they occur only in Region III. Table 22 shows lead and oils contained in spent clay. Data on other metals in spent clay from acid or caustic pretreated oil are skimpy and too uncertain to extrapolate. However, it is reasonable to assume that such metals as copper, chromium, and zinc are found in the waste.

## 4.7 Rationale for Extrapolation of Waste Quantities for 1977 and 1983

The difficulties in making projections for the rerefining

TABLE 39

DISTRIBUTION BY EPA REGIONS OF METALS AND OTHER SUBSTANCES IN ACID SLUDGE FOR 1975
(metric tons/year - dry weight)

| EPA REGIONS | I | II | III | IV | V | VI | VII | VIII | IX | X | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Arsenic | 0 | 0.12 | 0 | 0.26 | 0.53 | 0.39 | 0.03 | 0.027 | 0.12 | 0.04 | 1.50 |
| Barium | 0 | 2.35 | 0 | 5.30 | 11.7 | 8.66 | 0.72 | 0.59 | 2.60 | 0.89 | 33.0 |
| Cadmium | 0 | 0.023 | 0 | 0.054 | 0.12 | 0.08 | 0.007 | 0.006 | 0.027 | 0.026 | 0.33 |
| Chromium | 0 | 0.09 | 0 | 0.22 | 0.46 | 0.34 | 0.03 | 0.03 | 0.11 | 0.04 | 1.50 |
| Copper | 0 | 0.28 | 0 | 0.65 | 1.41 | 1.04 | 0.09 | 0.07 | 0.32 | 0.11 | 4.0 |
| Lead | 0 | 46.9 | 0 | 107.7 | 233.0 | 173.2 | 14.5 | 11.9 | 53.5 | 17.8 | 658.5 |
| Zinc | 0 | 4.7 | 0 | 11.3 | 24.6 | 18.2 | 1.53 | 1.25 | 5.6 | 1.88 | 69.1 |
| Aluminum | 0 | 0.82 | 0 | 1.89 | 4.11 | 3.04 | 0.26 | 0.21 | 0.94 | 0.31 | 11.6 |
| Boron | 0 | 0.08 | 0 | 0.19 | 0.41 | 0.3 | 0.02 | 0.02 | 0.09 | 0.03 | 1.14 |
| Calcium | 0 | 14.1 | 0 | 32.3 | 70.2 | 51.9 | 4.4 | 3.6 | 16.1 | 5.4 | 198.0 |
| Iron | 0 | 4.0 | 0 | 9.2 | 19.9 | 14.7 | 1.2 | 1.0 | 4.6 | 1.5 | 56.1 |
| Magnesium | 0 | 1.9 | 0 | 4.3 | 9.3 | 6.9 | 0.6 | 0.5 | 2.1 | 0.7 | 26.3 |
| Nickel | 0 | 0.05 | 0 | 0.11 | 0.24 | 0.17 | 0.01 | 0.01 | 0.05 | 0.02 | 0.60 |
| Phosphorus | 0 | 7.0 | 0 | 16.1 | 35.1 | 26.0 | 2.2 | 1.8 | 8.0 | 2.7 | 103.2 |
| Silicon | 0 | 3.3 | 0 | 7.5 | 16.4 | 12.1 | 1.0 | 0.08 | 3.8 | 1.3 | 46.2 |
| Sodium | 0 | 9.4 | 0 | 21.5 | 46.9 | 34.7 | 2.9 | 2.4 | 10.6 | 3.6 | 131.9 |
| Tin | 0 | 0.07 | 0 | 0.16 | 0.35 | 0.26 | 0.02 | 0.02 | 0.08 | 0.03 | 1.0 |
| Vanadium | 0 | 0.06 | 0 | 0.10 | 0.21 | 0.16 | 0.01 | 0.01 | 0.05 | 0.02 | 0.6 |
| Total | 0 | 95.3 | 0 | 218.9 | 474.2 | 356.1 | 29.5 | 23.5 | 108.7 | 36.4 | 1345.4 |
| Acid | 0 | 713.7 | 0 | 1625.8 | 3509.2 | 2597.2 | 218.1 | 178.4 | 812.8 | 267.7 | 9913.0 |
| Oils, Polymers Polar Compounds & Asphalts | 0 | 842.6 | 0 | 1942.4 | 4216.7 | 3121.2 | 215.3 | 216.0 | 968.1 | 327.0 | 11896.3 |

## TABLE 21

### QUANTITY DISTRIBUTION OF METALS AND OTHER SUBSTANCES IN CAUSTIC AND OTHER SLUDGE * 1975

| Constituent | PPM | Total U.S. Metric Tons/yr - dry weight |
|---|---|---|
| Arsenic | 45 | 0.37 |
| Barium | 1,000 | 8.2 |
| Cadmium | 8 | 0.06 |
| Chromium | 18 | 0.15 |
| Copper | 48 | 0.39 |
| Lead | 20,000 | 163.60 |
| Silver | 1 | 0.008 |
| Zinc | 1,500 | 12.29 |
| | | |
| Aluminum | 24 | 0.196 |
| Boron | 10 | 0.08 |
| Calcium | 1,000 | 8.18 |
| Iron | 350 | 2.86 |
| Nickel | 15 | 0.127 |
| Phosphorus | 1,100 | 8.998 |
| Silicon | 1,500 | 12.27 |
| Sodium | 4,000 | 32.72 |
| Tin | 70 | 0.573 |
| | | |
| Oil Polymers, Polar Compounds & Asphalt | 33% | 2,699 |

* Caustic and other sludges generated only in Regions II and III.

## TABLE II

## LEAD AND OILY CONSTITUENTS OF SPENT CLAY GENERATED IN THE PETROLEUM REREFINING INDUSTRY IN 1975

(metric tons/year - dry weight)

| EPA Regions | I | II | III | IV | V | VI | VII | VIII | IX | X | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Lead* | 0 | 7.66 | 4.17 | 60.76 | 45.1 | 65.32 | 1.0 | 3.36 | 3.60 | 0.5 | 191.55 |
| Oily** | 0 | 273.6 | 144.0 | 595.2 | 1085.4 | 731.4 | 36.3 | 120.0 | 131.4 | 18.0 | 3,140.6 |

Total spent clay generated in U.S. = 15,7000 tons

* No analytical data available on other metals except clay-only process.

** Oily: Includes polymers, polar compounds and asphaltenes.

industry are formidable. The steady decline of the industry since 1960 (82%) has been discussed in earlier sections. The industry, despite a reduction of 10% in the number of operating rerefiners in 1975 showed an increase in production of 4.7% or 9.1 million gallons over the previous year. This increase was effected by 44% of the rerefiners while 41% showed decreased production of 4.8 million gallons. The 1977 extrapolation is based on an anticipated 30% increase in 1977 (20.9 million gallons) by the rerefiners showing 1975 increases. Some rerefiners who showed decreased production and those who contemplate cessation of rerefining are estimated at a reduction of 2.9 million gallons. Total net increases projected are 18 million gallons or 35.4%. One new rerefiner anticipates production of 16 million gallons in 1977 and one anticipates an increase of 2 million gallons increase. Waste generation in the former case is difficult to establish, since no production experience is available and the form of pretreatment has not been decided. It is expected that a lower order of magnitude of sludge and bottoms will be generated and a 12% sludge generation has been estimated vs. the average of the more traditional process methods. Since the aforementioned plant will hydrotreat instead of using clay there will be no spent clay generation. The rerefinery which anticipates an annual 2 million increase has reduced sludge generation and, with a new proprietary method, expects to reduce the percentage of sludge even more. Therefore, a 10% factor for estimating sludge generation has been used in this case. Clay generation will increase in the same traditional proportion of 0.4 pounds per gallon of waste oil rerefined. The other existing rerefiners expected to increase production of oil will generate sludge and clay at the current rate.

The lead content of petroleum rerefining sludge in 1977 is estimated at 75% of the 1975 level, reflecting the increased use of no lead and low lead gasoline. The estimate for lead content for sludge generated in 1983 is based on a projected reduction of 75% of the 1975 level. Possible changes of regulations affecting the lead content of gasoline by governmental agencies may have an effect on these projections.

Projections for 1983 indicate that only 13 of the present rerefiners will be in operation, of which 12 will increase production to 150% of the present production levels. One rerefinery plans to increase production by 100% to 20 million gallons. Five new rerefiners will produce a total of 75 million gallons. Total production is projected at 193 million gallons.

The increase in production is predicated on two primary considerations: 1) favorable governmental action in restricting uncontrolled burning of waste oil, and 2) shortages of lubricating oil with increased prices for virgin oils. Other factors which would have beneficial effects are reimposition of the Federal Excise Tax, which gave the rerefiners a competitive edge prior to 1965 and deletion of the restriction against use of rerefined oil in military oil specifications. Improved rerefining methods, primarily elimination of acid pretreatment, increased utilization of sludge, or bottoms, clay reclamation, or use of hydrotreating in larger operations, will further the growth of the industry with potential reduction in hazardous waste disposal problems. Increased use of non-leaded gasoline along with the elimination of acid use will greatly reduce the environmental impact of disposal methods currently presented by these substances.

The projections for sludge and clay generation assume that the wastes can be utilized as fuel by the new and larger rerefineries or converted to useful products. Putscher shows that over fifty percent of acid sludge consists of organic substances. This portion is comprised of approximately thirty three percent each of lubricating oil, polymers, and asphalt. Large scale rerefining offers possibilities for processing the waste for by-product recovery. Clay regeneration and reuse has been practiced by virgin oil refiners and, here again, large scale production would allow economical reclamation of the spent clay. However, it has been shown that wastes are generated at lower levels than those resulting from current operations based on expectations of improved pretreatment methods. It is assumed that the five new plants will use clay in initial operations and switch to hydrotreating at levels of 30 million gallons per year; therefore, eliminating the generation of spent clay by these rerefiners. While this could occur before 1983, the 1983 projections do not include this adjustment, since it is expected that these new plants will begin operations using clay and if, and when, sufficient volumes are achieved(30 million or more gallons per year) will switch to hydrotreating.

For the purposes of this study the potential effect of synthetic lubricants now being test marketed has not been considered. Widespread use of these could have a dramatic effect on the rerefining industry, including new technology for rerefining these fluids.

## 4.8 Waste Quantities Projected for 1977 and 1983

### 4.8.1 Projections of Petroleum Rerefining Wastes in 1977

Table 23 shows projected total production and generation of oil rerefining wastes for 1977 by EPA Regions and the national total. Table 23 estimates are based on an increase in production of rerefined oils by a factor of approximately 1.35. However, acid sludge increases by a factor of 1.17. These projections reflect the greater use of non-acid pretreatments. The oils,

## TABLE 23

## ESTIMATED 1977 PRODUCTION OF PRODUCT AND GENERATION OF WASTES BY THE PETROLEUM REREFINING INDUSTRY

(metric tons/year - dry weight)

| EPA Regions | Oil Production ($10^3$ gal/yr) | SLUDGE | | Clay | Total Waste |
|---|---|---|---|---|---|
| | | Acid | Caustic, others | | |
| I | 0 | 0 | 0 | 0 | 0 |
| II | 15,200 | 2,995 | 10,870 | 1,697 | 15,562 |
| III | 3,300 | 0 | 4,557 | 466 | 5,023 |
| IV | 8,115 | 7,483 | 0 | 3,464 | 10,947 |
| V | 24,535 | 14,568 | 0 | 6,694 | 21,262 |
| VI | 10,400 | 8,104 | 0 | 5,477 | 13,581 |
| VII | 2,350 | 1,130 | 0 | 850 | 1,980 |
| VIII | 1,150 | 600 | 0 | 600 | 1,200 |
| IX | 3,270 | 2,622 | 0 | 820 | 3,442 |
| X | 575 | 1,228 | 0 | 121 | 1,349 |
| Total | 68,895 | 38,730 | 15,427 | 20,189 | 74,346 |

polymers, polar compounds and asphalt volume remain substantially the same in 1977 as in 1975 reflecting potential improvement in process methods with decreased losses of petroleum oil contained in sludge and clay.

Table 34 shows total hazardous constituents of all rerefining wastes, but reflects oils and lead only for spent clay since no complete analytical data is available. The largest quantities of acids and other potentially hazardous wastes occur in Region V, in which the larger rerefineries operate, which accounted for 35% of rerefined oil produced. In the U.S. in 1977, it is projected that expansion of existing rerefineries will occur in EPA Regions showing the current higher production volumes.

No acid sludge is generated in Region III since the two rerefiners use caustic pretreatment processes. Most of the planned increased production in this Region is expected to use a non-acid pretreatment and use of hydrotreating in place of clay treatment.

Tables 35, 36, 37 show projected 1977 quantities of metals, oil, polar compounds, and acid found in sludges and spent clay. Data for such constituents in spent clay are unavailable except for lead and oil (including polymers, etc.).

## TABLE 24

## TOTAL POTENTIALLY HAZARDOUS CONSTITUENTS IN WASTES GENERATED BY THE PETROLEUM REREFINING INDUSTRY IN 1977

(metric tons/year - dry weight)

| EPA | Constituents | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Regions | Acid | Oils | As | Ba | Cd | Cr | Cu | Pb | Zn |
| I | * | * | * | * | * | * | * | * | * |
| II | 895.0 | 5,390.8 | 0.65 | 12.0 | 0.10 | 0.55 | 1.66 | 216.4 | 29.1 |
| III | 0 | 1,733.7 | 0.2 | 4.6 | 0.3 | 0.18 | 0.55 | 70.6 | 9.6 |
| IV | 2,244.9 | 2,314.7 | 0.34 | 7.48 | 0.06 | 0.3 | 0.9 | 126.8 | 15.7 |
| V | 4,370.4 | 6,374.3 | 0.63 | 14.57 | 0.11 | 0.6 | 1.75 | 246.4 | 58.3 |
| VI | 1,431.2 | 3,896.5 | 0.36 | 8.10 | 0.05 | 0.32 | 0.16 | 142.2 | 17.0 |
| VII | 339.0 | 463.4 | 0.51 | 1.13 | 0.01 | 0.05 | 0.14 | 18.2 | 2.4 |
| VIII | 180.0 | 336.0 | 0.27 | 0.6 | 0.005 | 0.02 | 0.07 | 11.5 | 1.3 |
| IX | 786.6 | 1,088.7 | 0.12 | 2.62 | 0.02 | 0.10 | 0.31 | 43.3 | 5.3 |
| X | 362.6 | 466.3 | 0.05 | 1.23 | 0.01 | 0.05 | 0.15 | 18.9 | 2.6 |
| Total | 11,615.5 | 22,266.5 | 3.1 | 52.3 | 0.68 | 2.2 | 5.6 | 893.3 | 141.7 |

Note: Includes only oils and lead in clay - others not available.

## TABLE 25

### TOTAL POTENTIALLY HAZARDOUS CONSTITUENTS IN ACID SLUDGE GENERATED BY THE PETROLEUM REREFINING INDUSTRY IN 1977
(metric tons/year - dry weight)

| EPA Regions | Constituents | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Acid | Oils* | As | Ba | Cd | Cr | Cu | Pb | Zn |
| I | | | | | - none - | | | | |
| II | 898.5 | 1,078.2 | 0.13 | 2.10 | 0.02 | 0.12 | 0.36 | 44.9 | 6.3 |
| III | | | | | - none - | | | | |
| IV | 2,244.9 | 1,721.9 | 0.34 | 7.48 | 0.06 | 0.3 | 0.9 | 112.2 | 15.7 |
| V | 4,370.4 | 5,244.5 | 0.65 | 14.7 | 0.11 | 0.58 | 1.75 | 218.5 | 30.6 |
| VI | 2,431.2 | 2,917.4 | 0.36 | 8.10 | 0.06 | 0.32 | 0.10 | 121.6 | 17.0 |
| VII | 339.0 | 406.8 | 0.51 | 1.13 | 0.01 | 0.05 | 0.14 | 17.0 | 2.4 |
| VIII | 180.0 | 216.0 | 0.27 | 0.6 | 0.005 | 0.02 | 0.37 | 9.0 | 1.3 |
| IX | 786.6 | 943.9 | 0.12 | 2.62 | 0.02 | 0.10 | 0.31 | 39.3 | 5.5 |
| X | 368.4 | 442.1 | 0.05 | 1.23 | 0.01 | 0.05 | 0.15 | 18.4 | 2.6 |
| Totals | 11,615.0 | 12,970.8 | 2.43 | 37.83 | 0.83 | 0.40 | 3.8 | 580.9 | 81.4 |

* Oils includes petroleum oils, polymers, polar compounds and asphalt.

## TABLE 26

## LEAD AND OILY CONSTITUENTS IN CAUSTIC AND OTHER SLUDGE GENERATED BY THE PETROLEUM REREFINING INDUSTRY IN 1977

(metric tons/year - dry weight)

| EPA Regions | Constituents | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Acid | Oils | As | Ba | Cd | Cr | Cu | Pb | Zn |
| II | 0 | 3,913.2 | 0.5 | 10.9 | 0.08 | 0.43 | 1.30 | 163.1 | 22.8 |
| III | 0 | 1,640.5 | 0.3 | 4.6 | 0.3 | 0.18 | 0.55 | 68.6 | 9.6 |
| Total | | 5,553.7 | 0.8 | 15.5 | 0.38 | 0.61 | 1.85 | 231.7 | 32.4 |

Note: Caustic and other sludge generated only in EPA Regions II and III.

## TABLE 27

## LEAD AND OILS IN SPENT CLAY GENERATED BY THE PETROLEUM REREFINING INDUSTRY IN 1977

(metric tons/year - dry weight)

| EPA Region | Total Clay | Oils | Pb |
|---|---|---|---|
| I | 0 | 0 | 0 |
| II | 1,697 | 339.4 | 7.1 |
| III | 466 | 93.2 | 2.0 |
| IV | 3,464 | 692.8 | 14.6 |
| V | 6,994 | 1,398.8 | 29.1 |
| VI | 5,477 | 1,095.4 | 23.0 |
| VII | 850 | 170.0 | 3.6 |
| VIII | 600 | 120.0 | 2.5 |
| IX | 820 | 164.0 | 3.4 |
| X | 121 | 24.2 | 0.5 |
| Total | 20,144 | 4,097.8 | 84.8 |

### 4.8.2 Projection of Petroleum Rerefining Wastes in 1983

Table 28 shows projected rerefined oil production and waste generation in EPA Regions for 1983. Five new and larger rerefineries plus increased production by surviving 1975 rerefineries are expected to produce 183.5 million gallons.

Table 29 lists total potentially hazardous constituents in estimates of wastes generated in 1983. The totals include only the lead and oils in spent clay. Oils include petroleum oils, polymers, polar compounds, and asphalt. Total lead quantities have been adjusted for the increased use of no-lead and low-lead gasolines. The figures also reflect lower volume of petroleum oil in the sludge than is found currently. Hydrotreating may replace clay treatment in some cases and, hence, eliminate clay usage. A factor of 3.6 was utilized to project an increase in production of 132.7 million gallons in 1983 over 1975. The generation of acid sludge decreases, however, from 33 thousand metric tons to 31.6 thousand metric tons as a result of declining use of acid pretreatment. Caustic or other pretreatment sludge generation is projected to rise by a factor of 7.3. However, total sludge and clay generated shows an increase by a factor of only

## TABLE 25

## ESTIMATED PRODUCTION OF REREFINED OIL AND POTENTIALLY HAZARDOUS WASTES GENERATED BY THE PETROLEUM REREFINING INDUSTRY IN 1983

(metric tons/year - dry weight)

| EPA Regions | Production Gal. $10^3$/yr | Waste |  |  | Total |
|---|---|---|---|---|---|
|  |  | Sludge |  | Clay |  |
|  |  | Acid | Caustic, Others |  |  |
| I | 15,000 | 0 | 6,840 | 4,500 | 11,340 |
| II | 33,000 | 3,280 | 11,440 | 1,333 | 18,013 |
| III | 19,000 | 0 | 9,120 | 6,700 | 15,820 |
| IV | 27,500 | 7,220 | 6,840 | 11,550 | 25,610 |
| V | 49,000 | 6,940 | 15,960 | 15,460 | 38,360 |
| VI | 13,000 | 6,078 | 0 | 5,075 | 11,953 |
| VII | 3,000 | 2,280 | 0 | 360 | 7,640 |
| VIII | 2,500 | 1,900 | 0 | 1,300 | 3,200 |
| IX | 20,500 | 4,180 | 6,840 | 5,300 | 16,320 |
| X | 1,000 | 760 | 0 | 200 | 960 |
| Total | 183,500 | 31,838 | 60,040 | 52,578 | 144,258 |

## TABLE 29

## TOTAL POTENTIALLY HAZARDOUS CONSTITUENTS GENERATED BY THE PETROLEUM REREFINERY INDUSTRY IN 1983
(metric tons/year - dry weight)

| EPA Region | Acid | Oils* | As | Ba | Cd | Cr | Cu | Pb | Zn |
|---|---|---|---|---|---|---|---|---|---|
| | | | Constituents | | | | | | |
| I | 0 | 4,682 | 0.41 | 9.1 | 0.07 | 0.36 | 1.09 | 45.8 | 19.2 |
| II | 684 | 1,879 | 0.96 | 21.5 | 0.16 | 0.86 | 2.58 | 110.0 | 45.1 |
| III | 0 | 6,350 | 0.55 | 12.1 | 0.09 | 0.48 | 1.46 | 70.5 | 25.5 |
| IV | 217 | 8,896 | 0.73 | 16.3 | 0.12 | 0.61 | 1.96 | 117.7 | 34.4 |
| V | 208 | 14,518 | 1.27 | 28.1 | 0.21 | 1.13 | 3.38 | 176.2 | 59.3 |
| VI | 182 | 3,739 | 0.27 | 6.1 | 0.05 | 0.24 | 0.75 | 66.2 | 12.8 |
| VII | 684 | 893 | 0.10 | 2.3 | 0.02 | 0.09 | 0.27 | 11.9 | 4.8 |
| VIII | 570 | 944 | 0.09 | 1.9 | 0.01 | 0.08 | 0.23 | 11.3 | 4.0 |
| IX | 125 | 6,327 | 0.60 | 13.3 | 0.10 | 0.56 | 1.59 | 74.1 | 28.0 |
| X | 228 | 314 | 0.03 | 0.8 | 0.01 | 0.03 | 0.09 | 4.1 | 1.6 |
| Total | 2,893 | 48,528 | 5.01 | 111.5 | 0.84 | 4.44 | 13.4 | 685.0 | 234.7 |

* Oils: includes petroleum oil, polymers, polar compounds and asphalt.

9.9 in 1983. The acid constituent drops from 9,900 metric tons to 2,900 metric tons. Lead also is projected to decrease from approximately 900 metric tons in 1975 to 700 metric tons in 1983.

Tables 30, 31, 32 show the distribution of potentially hazardous constituents in acid sludge, caustic and other sludge, and spent clay respectively for 1983.

## 4.9. Future Process Changes in Rerefining

Two rerefiners using caustic soda pretreatment and four using the clay-only process, with no pretreatment, are producing rerefined oils. Various other chemical and solvent extraction pretreatments are noted in patent literature and practiced to some degree in Europe. There has been some pilot plant work done on solvent extraction of unwanted constituents from waste oils. Solvent extraction is widely used in virgin oil refining. Laboratory and pilot plant total vacuum distillation of waste oil which was not pretreated is also reported. These processes indicate that acid pretreatment is not the only feasible way to rerefine waste oils. All of these methods prepare the waste oil for distillation and post treatment by removing sludge materials.

However, these non-acid sludges or bottoms offer the

## TABLE 30

## TOTAL POTENTIALLY HAZARDOUS CONSTITUENTS IN ACID SLUDGE GENERATED BY THE PETROLEUM REREFINING INDUSTRY IN 1983

(metric tons/year - dry weight)

| EPA | | | Constituents | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Regions | Acid | Oils* | As | Ba | Cd | Cr | Cu | Pb | Zn |
| I | 0 | | | | | | | | |
| II | 684.0 | 820.8 | 0.10 | 2.28 | 0.03 | 0.09 | 0.27 | 11.4 | 4.8 |
| III | 0 | | | | | | | | |
| IV | 216.6 | 2,599.2 | 0.32 | 7.22 | 0.05 | 0.29 | 0.87 | 36.1 | 15.2 |
| V | 208.2 | 2,498.4 | 0.31 | 6.94 | 0.05 | 0.28 | 0.83 | 34.7 | 14.6 |
| VI | 182.3 | 2,188.8 | 0.27 | 6.08 | 0.05 | 0.24 | 0.73 | 30.4 | 12.8 |
| VII | 684.0 | 820.8 | 0.10 | 2.28 | 0.02 | 0.09 | 0.27 | 11.4 | 4.8 |
| VIII | 570.0 | 584.0 | 0.09 | 1.90 | 0.01 | 0.08 | 0.23 | 9.5 | 4.0 |
| IX | 125.4 | 1,504.8 | 0.19 | 4.18 | 0.03 | 0.16 | 0.5 | 20.9 | 8.8 |
| X | 278.0 | 273.6 | 0.03 | 0.76 | 0.01 | 0.03 | 0.09 | 3.81 | 1.6 |
| Total | 2,898.50 | 11,290.40 | 1.40 | 31.60 | 0.24 | 1.26 | 3.80 | 159.2 | 66.60 |

* Oils: includes petroleum oil, polymers, polar compounds and asphalt

## TABLE 31

## TOTAL POTENTIALLY HAZARDOUS CONSTITUENTS IN CAUSTIC & OTHER SLUDGE GENERATED BY THE PETROLEUM REREFINING INDUSTRY IN 1983

(metric tons/year - dry weight)

| EPA | Constituents | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Regions | Oils* | As | Ba | Cd | Cr | Cu | Pb | Zn |
| I | 3,762 | 0.41 | 9.1 | 0.07 | 0.36 | 1.09 | 45.8 | 19.2 |
| II | 7,920 | 0.86 | 19.2 | 0.14 | 0.77 | 2.31 | 96.7 | 40.3 |
| III | 5,016 | 0.55 | 12.1 | 0.09 | 0.48 | 1.46 | 61.1 | 25.5 |
| IV | 3,762 | 0.41 | 9.1 | 0.07 | 0.36 | 1.09 | 45.8 | 19.2 |
| V | 8,778 | 0.96 | 21.2 | 0.16 | 0.85 | 2.55 | 106.9 | 44.7 |
| VI | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| VII | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| VIII | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| IX | 3,762 | 0.41 | 9.1 | 0.07 | 0.36 | 1.09 | 45.8 | 19.2 |
| X | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Total | 33,000 | 3.6 | 79.8 | 0.6 | 3.2 | 9.6 | 402.1 | 168.1 |

* Oil's: Includes petroleum oils, polymers, polar compounds and asphalt.

## TABLE 32

## TOTAL POTENTIALLY HAZARDOUS CONSTITUENTS IN SPENT CLAY GENERATED BY THE PETROLEUM REREFINING INDUSTRY IN 1983

(metric tons/yr - dry weight)

| EPA Regions | Constituents<br>Oils | <br>Pb |
|---|---|---|
| I | 900 | 6.3 |
| II | 266 | 1.9 |
| III | 1,340 | 9.4 |
| IV | 2,535 | 35.8 |
| V | 3,242 | 32.6 |
| VI | 1,550 | 35.5 |
| VII | 72 | 0.5 |
| VIII | 260 | 1.8 |
| IX | 1,060 | 7.4 |
| X | 40 | 0.3 |
| Total | 11,265 | 131.8 |

rerefiner more options for use of the sludge as fuel, or for by-product recovery, than the acid sludge. EPA sponsored an investigation of lead recovery possibility using caustic sludge as part of the fuel for a lead reverberatory furnace.[24] It was concluded that more appropriate burners and better control could make this recovery method viable. Canada's Environmental Protection Service sponsored an investigation of the suitability of waste oil fuel for cement kilns with good results.[25] It is reasonable to assume that non-acid sludge with rerefining distillate or raw waste oil could be used in this manner.

## 5.0 Waste Treatment and Disposal Technology

### 5.1 Introduction

This section discusses the three levels of technology employed by the oil rerefining industry in disposing of 41,225 tons of sludge and 15,700 tons of spent clay in 1975. The sludge total includes very small and unknown amounts of tank bottoms and wastewater treatment sludge. Level I is the most prevalent technology; Level II, the best available technology; and Level III, the technology required for adequate health and environmental protection.

Petroleum rerefining sludge, clay, and untreated wastewaters, particularly that produced by steam stripping during distillation, are considered to be potentially hazardous wastes due to the acid, metals, and hydrocarbon constituents contained in the wastes.

## 5.2 Hazardous Waste Management Overview

### 5.2.1 Sludge and Clay Waste Management

Twenty two, or 81%, of the rerefineries dispose of both sludge and spent clay in landfills or on roads without any form of treatment. Only one rerefiner uses a clay-lined lagoon for disposal of acid sludge. Four rerefiners, 14.8% of the industry treat the sludge or clay for landfill disposal. One rerefiner is treating both sludge and clay for on-site disposal with cement dust to neutralize acids and to fix metals, phenols, and hydrocarbon hazardous wastes. Another sends sludge and clay to a commercial operator who mixes the sludge and clay with a mixture of limestone dust and other wastes. The other two rerefiners neutralize the sludge with lime, in one case, and with the calcium hydroxide by-product of acetylene manufacturing in the other case. While the lime and calcium hydroxide will neutralize acid, there are no data on leaching of these. Tests, under EPA sponsorship, are being performed by the Army Corps of Engineers at Vicksburg, Mississippi on mixtures of acid sludge/cement dust and spent clay/cement dust prepared by a nearby rerefiner with recently installed equipment. Preliminary and incomplete test results on bench scale mixing showed 9.6 PPM of lead in the leachate from an acid sludge/cement dust mixture.[26] The raw sludge had approximately 29,000 PPM of lead. It is hoped that even more mixing and possible use of a secondary fixative agent will prevent leaching of more than the 0.05 PPM lead to meet the EPA Interim Drinking Water standards. One rerefiner ships his sludge to a municipal landfill which handles large quantities of fly ash. This alkaline material neutralizes the sludge in the ordinary operation of the landfill.

One rerefiner disposes of approximately 50% of his caustic pretreatment sludge by adding it to a large quantity of residual fuel. Burning tests conducted by major oil companies and tests sponsored by EPA have shown that waste crankcase oil mixed with virgin fuel in percentages of 5% does not emit potentially hazardous quantities of lead and other particulates beyong the limits of air quality standards.[27] One major utility concluded that 25% of settled crankcase oil mixed with residual fuel could be used in the boilers and meet acceptable air pollution standards.[28] Therefore, sufficient dilution of this caustic sludge may be acceptable with adequate emission controls. Here, as in any burning of wastes derived from oil rerefining, the ultimate destination of hazardous substances, such as lead in fly ash, and other residues of combustion must ultimately be addressed and the question of dilution as the answer to pollution.

Two rerefiners, one using a caustic process, the other a proprietary process (using neither acid nor caustic) sell their sludge to asphalt compound manufacturers for use as an extender and plasticizer. While no leach tests of finished asphalt products have been made, it seems reasonable to assume that the asphalt fixes such contaminants as lead and, at worst, allows only negligible amounts of contaminants to be leached.

All twenty-seven rerefiners dispose of spent clay in landfills or on roads. Nineteen (70.4%) use off-site landfills for untreated clay. Ten rerefiners use their own trucks. The spent clay of the remaining nine is hauled by contractors. Only five rerefiners (48.5%) use municipal landfills. The spent clay of three rerefiners and one third of that generated by a fourth rerefiner is applied to roads. Four rerefiners (15%) dispose of spent clay on-site. One of these mixes the clay with cement dust. The others have no treatment method.

One rerefiner uses a commercial firm as a disposal method, which uses a lime dust mixture as a fixative for landfill preparation. Six rerefiners use contractors who truck the waste to landfills. In three of these cases, 11.1% of the industry, the ultimate disposal site for spent clay is unknown to the rerefiner. The spent clay of two of the remaining three is handled by a large and reputable firm with apparent adequate safeguards. A third temporarily stores the clay after mixing with wastewater in an on-site water lagoon. Periodically a contractor removes the clay with a drag line, spreads it on the lagoon bank and, after drying, loads and trucks the clay to a landfill site.

Eight, or 29.6%, of the rerefiners haul spent clay to commercial landfills, while five, or 18.5%, use sites operated by cities or counties. One of these disposes of approximately equal amounts of spent clay in a municipal landfill, on roads, and on-site. The 625 tons generated by this rerefiner is listed in this section under the municipal landfill category, although the quantities have been distributed in quantity and cost analysis totals to the road and on-site sections.

Three other rerefiners dispose of all of the clay generated for use on roads. They constitute

11.1% of the industry. The three remaining rerefiners dispose of spent clay on-site without treatment, although two mix clay with soil on a periodic basis.

Tables 33 and 34 show quantity distribution of wastes by various disposal/technology methods. Since only one rerefiner uses a lagoon for sludge the total for this operation has been included under the column heading, "Landfill-on-site, untreated" in Table 33. Tables 35 and 36 show the quantity of wastes disposed by rerefiners in each EPA Region.

### 5.2.2 Process Wastewater Management

Rerefining generates three wastewater streams; raw waste oil tank bottoms, cooling water, and steam stripping water. The first is negligible and often is removed at the dehydration step before pretreatment and becomes part of the sludge or is added to the water recycle and disposal system. The second, which contains no contaminants, is recycled. The third, generated at the distillation step, is neutralized and oil is separated in all cases.

The following summary table lists the disposal methods of the excess process waters generated by petroleum rerefiners.

## TABLE 33

## QUANTITIES OF WASTE DISPOSED VIA LEVEL I TREATMENT/DISPOSAL TECHNOLOGY IN 1975 BY THE PETROLEUM REREFINING INDUSTRY

| | | Percent of | | Rerefiners | |
|---|---|---|---|---|---|
| Waste | Quantity (dry wt) Metric tons/yr | Each Waste | Total Waste | Number | % of Total |
| **Off-Site Landfill, untreated** | | | | | |
| Acid Sludge | 23,615 | 95.3 | 41.5 | 13 | 48.1 |
| Caustic Sludge | 0 | 0 | 0 | 0 | 0 |
| Spent Clay | 11,930 | 76.0 | 21.0 | 19 | 70.4 |
| Total | 35,545 | | 62.4 | | |
| **Off-Site Roads, untreated** | | | | | |
| Acid Sludge | 910 | 3.0 | 2.0 | 1 | 3.7 |
| Caustic Sludge | 1,440 | 17.6 | 2.5 | 1 (1) | 3.7 |
| Spent Clay | 1,097 | 7.0 | 2.0 | 3 (1) | 11.1 |
| Total | 3,447 | | 6.1 | | |
| **Off-Site Fuel, untreated** | | | | | |
| Acid Sludge | 0 | 0 | 0 | 0 | 0 |
| Caustic Sludge | 1,440 | 17.6 | 2.5 | 1 | 3.7 |
| Spent Clay | 0 | 0 | 0 | 0 | 0 |
| Total | 1,440 | | 2.5 | | |
| **On-Site Landfill, untreated** | | | | | |
| Acid Sludge | 2,470 | 8.1 | 4.6 | 2 | 7.4 |
| Caustic Sludge | 0 | 0 | 0 | 0 | 0 |
| Spent Clay | 1,208 | 7.7 | 2.1 | 4 (1) | 14.8 |
| Total | 3,678 | | 6.8 | | |

(1) Two rerefiners dispose of sludge or clay in more than one category.

## TABLE 34

## QUANTITIES OF WASTE DISPOSED VIA LEVEL II TREATMENT/DISPOSAL TECHNOLOGY IN 1975 BY THE PETROLEUM REREFINING INDUSTRY

| Waste | Quantity (dry wt) Metric tons/yr | Percent of Each Waste | Percent of Total Waste | Rerefiners Number | Rerefiners % of Total |
|---|---|---|---|---|---|
| Off-Site<br>Landfill,treated | | | | | |
| Acid Sludge | 3,375 | 10.2 | 5.9 | 3 | 11.1 |
| Caustic, other sludge | 0 | | | 0 | |
| Spent Clay | 965 | 6.1 | 1.7 | 1 | 3.7 |
| Total | 4,340 | | 7.6 | | |
| On-Site<br>Landfill, treated | | | | | |
| Acid Sludge | 2,475 | 7.5 | 4.3 | 1 | 3.7 |
| Caustic, other sludge | 0 | | | 0 | |
| Clay | 500 | 3.2 | 0.8 | 1 | 3.7 |
| Total | 2,975 | | 5.1 | | |
| Waste Converted to Product (other than fuel) | | | | | |
| Acid Sludge | 0 | | | 0 | |
| Caustic, other sludge | 5,300 | 64.8 | 9.3 | 2 | 7.4 |
| Clay | 0 | | 0 | 0 | |
| Total | 5,300 | | 9.3 | | |

## TABLE 35

### THE QUANTITY OF NEUTRALIZING ACID, CAUSTIC & OTHER SLUDGES DISPOSED BY EPA REGIONS & SITES IN 1975

(metric tons/year - dry weight)

| EPA Regions | LANDFILL - OFF-SITE Municipal Treated (2) | Municipal Untreated | Commercial Treated | Commercial Untreated | ROADS(1) | FUEL(1) | PRODUCT(1) | LANDFILL-ON-SITE Treated | LANDFILL-ON-SITE Untreated | Total |
|---|---|---|---|---|---|---|---|---|---|---|
| I | | | | | | | | | | |
| II | | 2,340 | | | 1,440 | 1,440 | | | | 5,220 |
| III | | | | | | | 5,300 | | | 5,300 |
| IV | | 420 | | 2,500 | | | | 2,475 | | 5,395 |
| V | | | 2,655 | 6,398 | | | | | 2,680 | 11,713 |
| VI | | | | 8,675 | | | | | | 8,675 |
| VII | | | 720 | | | | | | | 720 |
| VIII | | 600 | | | | | | | | 600 |
| IX | | 432 | | 2,250 | | | | | | 2,682 |
| X | | | | | 950 | | | | | 950 |
| Total | | 3,792 | 4,375 | 19,823 | 2,390 | 1,440 | 5,300 | 2,475 | 2,522 | 41,225 |
| % of total sludge | | 9.2 | 10.6 | 48.1 | 5.7 | 3.5 | 12.8 | 6.0 | 6.5 | 100% |

Note: All landfills reported to be State approved.

(1) Use of sludge on roads, as fuel or in products, considered as off-site disposal for this study.

(2) "Treated" includes mixing with cement dust, lime, or other alkaline materials which neutralize acids. Degree of fixation has not been determined.

## TABLE 36

## THE QUANTITY OF REREFINING SPENT CLAY DISPOSED BY EPA REGIONS & SITES IN 1975

(metric tons/year - dry weight)

| EPA Regions | LANDFILLS - OFF-SITE Municipal Treated | Municipal Untreated | Commercial Treated | Commercial Untreated | ROADS | LANDFILL - ON-SITE Treated | Untreated | Total |
|---|---|---|---|---|---|---|---|---|
| I | | | | | | | | |
| II | | 600 | | 760 | | | | 1,360 |
| III | | | | 120 | | | 625 | 745 |
| IV | | 1,860 | | 620 | | 500 | | 2,976 |
| V | 234 | | 965 | 3,653 | 500 | | 75 | 5,427 |
| VI | | 209 | | 3,032 | 208 | | 208 | 3,457 |
| VII | | | | 380 | | | | 380 |
| VIII | | 600 | | | | | | 600 |
| IX | | 132 | | 96 | 309 | | | 657 |
| X | | | | 90 | | | | 90 |
| Total | 234 | 3,447 | 965 | 8,540 | 1,097 | 500 | 908 | 15,700 |
| % of Total | 1.5 | 22.0 | 6.1 | 54.5 | 7.0 | 3.2 | 5.8 | 100 |

**Petroleum Rerefining Excess Process Water Disposal**

| Disposal Method | Number of Rerefiners | Percent of Rerefiners |
|---|---|---|
| Sanitary sewers | 13 | 48.0 |
| Drainage ditches | 5 | 18.5 |
| Municipal landfills | 1 | 3.7 |
| Disposal well | 2 | 7.4 |
| Contractor | 1 | 3.7 |
| Incineration | 1 | 3.7 |
| Zero discharge | 4 | 14.8 |
| | 27 | 99.8 |

Very few rerefiners keep detailed records of wastewater volume.

Only two rerefiners, 7.4%, utilize the more sophisticated water treatment methods such as coagulation, air flotation, and clarification. Gravity separation, in one form or another, such as in tanks, pits, or lagoons, is practiced by all rerefiners to remove oils and solids.

## 5.3 Alternative Treatment and Disposal Methods

### 5.3.1 Introduction

The best method of improving the disposal technology of rerefining wastes is the employment of pretreatment methods other than acid treatment and post treatment, such as hydrotreating, which would eliminate the use of clay.

Production of high quality rerefined oils requires removal of non-petroleum oil constituents. These include solids, water additive compounds, such as detergents and viscosity index improvers, which are part of the original oil, compounds formed during use, such as oxidates and resins, and those added to the oil, such as tetraethyl lead from gasoline.

Resource recovery is a feasible goal. The operations of two rerefiners demonstrate this possibility. The processed sludge is used as an asphalt product extender and plasticizer. Other processing, such as solvent dilution and filtration, could produce metals, such as lead, and a material with good extreme pressure lubricating properties for specialty lubricants from the original additives and compounds formed during use. Larger volume could produce sufficient sludges or bottoms for possible reclamation and reuse of additives. Sludge, treated to remove objectionable materials, such as lead, could be used as industrial fuel without excessively expensive air pollution control equipment, and certainly, an in-plant fuel which would not require the air pollution control equipment for an untreated material.

### 5.3.2 Sludge Burning

The use of equipment and methods, such as incinerators, reverberatory furnaces, fluid bed furnaces, pyrolysis for burning used oils, and, by extension, highly diluted non-acid sludge, have been mentioned in the literature.[5,20,24,29] Preliminary experimentation of acid sludge burning by one rerefiner points to the possibility of on-site burning even of acid sludge. The major problem in burning of acid sludge is achieving a homogeneous mixture with a viscosity reducer such as rerefinery produced distillate.[30] Heater or boiler materials of construction must also be considered because of the potential corrosion and erosion possibilities.

### 5.3.3 Chemical Fixation

Chemical fixation is being used for oily wastes from sources other than rerefining. One of these uses sodium silicate with very good fixation results. However, this method is too costly for the petroleum rerefining acid sludge due to the high acid content. A method for removal of the inorganic acid (sulfuric acid) would allow more efficient and less costly chemical fixation.

### 8.3.4 Clay Reclaiming

Clay presents a less difficult disposal problem. First, the hazardous constituents are present in greatly reduced quantities. Second, a large part of the hazardous constituents can be removed by washing with solvents and even a water/detergent mixture. A final burning in a kiln to remove occluded materials provides a reclaimed and reusable material. Reclamation of spent clay and activated carbon is widely practiced in petroleum and chemical processing.

### 8.3.5 Wastewater Recycle

Rerefining uses large quantities of water for cooling and steam stripping. Cooling water is not contaminated by oils or other contaminants and can be and is recycled.

Steam stripping water, after oil (hexane solubles) removal can be treated by well established wastewater treatment methods, such as coagulation, flocculation, air flotation, and filtration. Such water can be reused in boilers. Minimal treatment of the water from steam stripping allows the water to be reused for cooling if not as boiler feed water. Two rerefiners use adequate wastewater treatment methods and four have zero discharge. Therefore, it is not impossible, difficult or even too expensive to achieve zero discharge with complete recycling. Sludge and solids from adequate water treatment are of small quantity compared with pretreatment sludge and spent clay. Inclusion in other wastes would add very little to the total disposal problem.

### 5.3.6 Large Scale Operations, Alternatives

It is possible that larger scale operations could use pyrolysis either on-site or in municipal pyrolysis units.[20] Here, most of the metals would be trapped in the char. The gas or liquid hydrocarbon could be used as plant fuel.

The use of two rerefiners' non-acid sludge as asphalt extender and plasticizer suggests resource recovery possibilities in several product areas.

Large scale rerefining operations can support the capital investment for hydrotreating equipment, thus replacing clay. Rerefined oils from bench and small pilot scale hydrotreating are reported to have excellent specifications.[31]

Given a favorable and profitable operating climate the rerefining industry has the potential for a resurgence and can fill an important resource recovery role with zero water discharge.

## 5.4 Level I, II, and III Treatment/Disposal Technologies for Hazardous Wastes

Twenty-one of the twenty-seven rerefiners use Level I technology for disposal of petroleum rerefining wastes.

Level II technology is being practiced by six rerefiners. Four neutralise wastes either on-site or use the services of a contractor while two use landfills considered secure by the author. There is no evidence, at this time, that these rerefiners utilise more than the best available technology and therefore, disposal practices by these rerefiners are placed in the Level II category.

At this point, there are no rerefiners using Level III technology. However, if current leach tests of sludge mixed with cement dust and clay mixed with the same material prevents leaching of potentially hazardous constituents, there may be an environmentally adequate and suitable disposal method.

Neutralisation of acid sludge removes the possibility of the acid waste being potentially hazardous but there is no evidence that such materials as lead compounds will not leach and migrate into the ground water.

Use of cement dust/acid sludge and cement dust/clay mixtures has been assigned a Level II designation.

Tables 37 and 38 describe Levels I, II, and III technology for sludge and spent clay for 1975. It is expected that there will be some improvement in the industry's disposal technology in 1977 with increased use of cement dust fixation, or some other effective technology, and greater use of a non-acid pretreatment process. The planned use of hydrotreating by one rerefiner with a projected annual production of 10 million gallons could eliminate approximately 3,800 tons of spent clay.

Tables 39 and 40 show projections of treatment/disposal technologies for 1977. Here again, the projected new plants, with 78 million gallons production, are expected to generate sludge in lower proportional quantity than that generated by current operations. Sludge quantities are shown in these tables although there is a good possibility that the sludge will be either processed as products or will be used as plant fuel.

Full industry compliance with environmental protection requirements will necessitate Level III disposal technology, such as use of secure landfills or adequate treatment of the waste to prevent leaching in landfills including on-site disposal. The 1983 projections show the three levels as the same in Tables 41 and 42.

## TABLE 37

## DISPOSAL TECHNOLOGY FOR [illegible] [illegible] WASTES -[illegible] SLUDGE IN 1975

| Factor | Level I<br>Prevalent Technology | Level II *<br>Best Available Technology | Level III, *Adequate Health & Environmental Protection |
|---|---|---|---|
| Physical and Chemical Properties | Off-site landfill, no neutralizing or fixation treatment | Cement or lime dust/sludge mixtures. Neutralizes & fixes | Neutralization with fixation & use of secure landfill |
| Amount of Wastes | 23,625 tons/year | 5,675 tons/year | 5,675 tons/year |
| Hazardous Factors | Oils, heavy metals & indicated carcinogenic possibility, leaching | Leaching of fixed materials if other wastes affect fixation | Same as Level II |
| Treatment/Disposal Technology | Placed in landfill and mixed with other waste | Neutralized, fixed and placed in secure landfill | Same as Level II |
| Number of Plants Using Technology | 17 | 2 | 1 current - 1 designing on-site secure landfill |
| Adequacy of Technology | Inadequate | Provisionally adequate | Same as Level II |
| Non Land Environmental Impact | Possible ground water contamination | Possible ground water contamination & odor control | Same as Level II |
| Problems and Comments | Economics | Economics - improved fixative properties | Same as Level II |
| Compatibility with Existing Facilities | No on-site facilities | Good | Good |
| Monitoring & Surveillance Techniques | Minimal to non existent depending on landfill operator | Used in secure landfill planned for on-site landfill | Same as Level II |
| Installation Time for New Facility | None contemplated | Eight months | Eight months |
| Energy Requirements | None | Relatively negligible, NA | Relatively negligible. NA |

* Provisional until outcome of EPA/Army Corps of Engineers leach tests.

## TABLE 38

## DISPOSAL TECHNOLOGY FOR PETROLEUM RE-REFINING WASTES-SPENT CLAY IN 1975

| Factor | Level I<br>Prevalent Technology | Level II *<br>Best Available Technology | Level III*-Adequate Health & Environmental Protection |
|---|---|---|---|
| Physical and Chemical Properties | Off-site landfill, no neutralizing or fixative treatment | Cement or lime dust/sludge mixtures. Neutralizes & fixes | Neutralization with fixation & use of secure landfill |
| Amount of Wastes | 8,583 tons/year | 6,519 tons/year | 7,555 tons/year |
| Hazardous Factors | Oils, heavy metals & indicated carcinogenic possibility, leaching | Leaching of fixed materials if other wastes affect fixation | Same as Level II |
| Treatment/Disposal Technology | Placed in landfill and mixed with other waste | Neutralized, fixed and placed in secure landfill | Same as Level II |
| Number of Plants Using Technology | 16 | 5 | 3 |
| Adequacy of Technology | Inadequate | Provisionally adequate | Same as Level II |
| Non Land Environmental Impact | Possible ground water contamination | Possible ground water contamination and odor control | Same as Level II |
| Problems and Comments | Economics | Economics - improved fixative properties | Same as Level II |
| Compatibility with Existing Facilities | No on-site facilities | Good | Good |
| Monitoring & Surveillance Techniques | Minimal to non existent depending on landfill operator | Good in secure landfill planned for on-site landfill | Same as Level II |
| Installation Time for New Facility | None contemplated | Eight months | Eight months |
| Energy Requirements | None | Relatively negligible, NA | Relatively negligible, NA |

* Provisional until outcome of EPA/Army Corps of Engineers leach tests.

TABLE 39

DISPOSAL TECHNOLOGY FOR [illegible] [illegible] WASTES - [illegible] SLUDGE IN 1977

| Factor | Level I<br>Prevalent Technology | Level II *<br>Best Available Technology | Level III * -Adequate Health & Environmental Protection |
|---|---|---|---|
| Physical and Chemical Properties | Off-site landfill, no neutralizing or fixation treatment | Cement or lime dust/sludge mixtures. Neutralizes & fixes | Neutralization with fixation & use of secure landfill |
| Amount of Wastes | 7,865 tons/year | 4,621 tons/year | 28,876 tons/year |
| Treatment/Disposal Technology | Placed in landfill and mixed with other waste | Neutralized, fixed and placed in secure landfill | Same as Level II |
| Hazardous Factors | Oils, heavy metals & indicated carcinogenic possibility, leaching | Leaching of fixed materials if other wastes affect fixation | Same as Level II |
| Number of Plants Using Technology | 5 | 3 | 6 |
| Adequacy of Technology | Inadequate | Provisionally adequate | Same as Level II |
| Non Land Environmental Impact | Possible ground water contamination | Possible ground water contamination & odor control | Same as Level II |
| Problems and Comments | Economics | Economics - improved [illegible] [illegible] proportion | Same as Level II |
| Compatibility with Existing Facilities | No on-site facilities | Good | Good |
| Monitoring & Surveillance Techniques | Minimal to non existent depending on landfill operator | Good in secure landfill planned for on-site landfill | Same as Level II |
| Installation Time for New Facility | None contemplated | Eight months | Eight months |
| Energy Requirements | None | Relatively negligible, NA | Relatively negligible, NA |

* Provisional until outcome of EPA/Army Corps of Engineers leach tests.

TABLE 40

DISPOSAL TECHNOLOGY FOR PETROLEUM RE-REFINING WASTES - SPENT CLAY IN 1977

| Factor | Level I<br>Prevalent Technology | Level II *<br>Best Available Technology | Level III * -Adequate Health & Environmental Protection |
|---|---|---|---|
| Physical and Chemical Properties | Off-site landfill, no neutralizing or fixation treatment | Cement or lime dust/clay mixtures. Neutralized & fixes | Neutralization with fixation & Use of secure landfill |
| Amount of Wastes | 11,930 tons/year | 1,465 tons/year | 1,465 tons/year |
| Hazardous Factors | Oils, heavy metals & indicated carcinogenic possibility, leaching | Leaching of fixed materials if other wastes affect fixation | Same as Level II |
| Treatment/Disposal Technology | Placed in landfill and mixed with other waste | Neutralized, fixed and placed in secure landfill | Same as Level II |
| Number of Plants Using Technology | 19 | 2 | 2 |
| Adequacy of Technology | Inadequate | Provisionally adequate | Same as Level II |
| Non Land Environmental Impact | Possible ground water contamination | Possible ground water contamination and odor control | Same as Level II |
| Problems and Comments | Economics | Economics - improved fixative properties | Same as Level II |
| Compatibility with Existing Facilities | No on-site facilities | Good | Good |
| Monitoring & Surveillance Techniques | Minimal to non existent depending on landfill operator | Good in secure landfill planned for on-site landfill | Same as Level II |
| Installation Time for New Facility | None contemplated | Eight months | Eight months |
| Energy Requirements | None | Relatively negligible, NA | Relatively negligible, NA |

* Provisional until outcome of EPA/Army Corps of Engineers leach tests.

TABLE 41

DISPOSAL TECHNOLOGY FOR PETROLEUM REFINING WASTES - NEUTRALIZATION SLUDGE IN 1983

| Factor | Level I<br>Prevalent Technology | Level II *<br>Best Available Technology | Level III * -Adequate Health & Environmental Protection |
|---|---|---|---|
| Physical and Chemical Properties | Neutralization & Chemical Fixation with on or off-site landfill | Same | Same as Level II |
| Amount of Wastes | 91,678 tons/year | 91,678 | 91,678 |
| Hazardous Factors | Oils, heavy metals & indicated carcinogenic possibility | Same | Same as Level II |
| Treatment/Disposal Technology | Neutralization, chemical fixation. Mixing with other wastes or on-site soil | Same | Same as Level II |
| Number of Plants Using Technology | 19 | 19 | 19 |
| Adequacy of Technology | Adequate | Same | Same as Level II |
| Non Land Environmental Impact | None | Same | Same as Level II |
| Problems and Comments | See note | Same | Same as Level II |
| Compatibility with Existing Facilities | Good | Same | Same as Level II |
| Monitoring & Surveillance Techniques | As required | Same | Same as Level II |
| Installation Time for New Facility | 8 months | Same | Same as Level II |
| Energy Requirements | Relatively negligible | Same | Same as Level II |

Note: It is pr[illegible]ed that all refiners will, of necessity, meet environmental standards & hence, all three level[illegible] the same.

TABLE 42

DISPOSAL TECHNOLOGY FOR PETROLEUM REFINING WASTES - SPENT CLAY IN 1983

| Factor | Level I<br>Prevalent Technology | Level II<br>Best Available Technology | Level III -Adequate Health & Environmental Protection |
|---|---|---|---|
| Physical and Chemical Properties | Neutralization & Chemical fixation with on or off-site landfill | Same | Same as Level II |
| Amount of Wastes | 52,578 | 52,578 | 52,578 |
| Hazardous Factors | Oils, heavy metals & indicates carcinogenic possibility | Same | Same as Level II |
| Treatment/Disposal Technology | Neutralization, chemical fixation. Mixing with other wastes or on-site soil. | Same | Same as Level II |
| Number of Plants Using Technology | 19 | 19 | 19 |
| Adequacy of Technology | Adequate | Same | Same as Level II |
| Non Land Environmental Impact | None | Same | Same as Level II |
| Problems and Comments | See note | Same | Same as Level II |
| Compatibility with Existing Facilities | Good | Same | Same as Level II |
| Installation Time for New Facility | 8 months | Same | Same as Level II |
| Energy Requirements | Relatively negligible | Same | Same as Level II |

Note: It is projected that all refiners will, of necessity, meet environmental standards and hence, all three levels are the same.

# 8.0 Cost Analysis

## 8.1. Introduction

Rerefining industry waste disposal costs vary widely for substantially the same materials. In general, the costs reported by rerefineries are low since in-plant waste handling or equipment costs are seldom separated in accounting records. Reported costs vary from $3.00 to $31.00 per ton of sludge and $1.00 to $15.00 for spent clay. Higher waste disposal costs are a reflection more of transportation costs than of more effective environmental disposal technology. For example, the $31.00 per ton cost includes a five hundred mile round trip, while a $15.00 per ton cost to a well-operated and secure landfill includes transportation by the contractor and a 10 mile trip to the landfill site.

Wastewater disposal cost data is inadequate. Neutralization of steam stripping water is part of the rerefining operation, as is the first gravity separation of distillate oil and water. Here again, few, if any, records of quantities or costs are available. The four rerefiners, who do not use a sewer or do not utilize a stream for disposal for wastewater disposal have excess wastewater quantities of 10,000 to 520,000/gallons/year. Costs range from zero to

$20.48/ton for incineration of this water.

In those cases where sludge is processed to produce a product, such as asphalt products plasticizer and extender, a zero cost or even negative cost results. As noted earlier, these have been included in this study as disposal methods rather than as by-products.

The industry disposal cost variation is also reflected in the add-on cost per gallon of product. Sludge disposal contributes $0.006 to $0.027 per gallon. Clay costs vary from $0.001 to $0.006 per gallon. Total cost per gallon of product ranges from $0.001 to $0.031 per gallon.

Thus, disposal costs, as a part of product costs, vary widely within the industry. Disposal costs for this industry also do not necessarily follow an increasing cost progression through the three levels of technology, although well managed landfills collect higher charges than others.

## 6.2 Techniques and Assumptions Used

Table 43 shows total disposal costs for sludge and clay and the disposal cost add-on per gallon of product of rerefined oil by EPA Regions. Weighted averages were utilized. For example, in Region II one rerefiner disposes of caustic sludge in fuel and on roads and this was taken

TABLE 43

WASTE DISPOSAL COSTS AND DISPOSAL COSTS PER GALLON OF REREFINED OIL BY EPA REGIONS IN 1975

| EPA Region | Sludge Quantity Tons/yr | Sludge Average Cost * Waste Ton | Sludge Average Cost * Gallon Product | Clay Quantity Tons/yr | Clay Average Cost Waste Ton | Clay Average Cost Product (gallon) | Total Wastes(ton) | Wastes Cost(ton | Total Cost (gallon) Product $ |
|---|---|---|---|---|---|---|---|---|---|
| I | - 0 - | | | - 0 - | | | - 0 - | | |
| II | 5,220 | $ 5.00 | $0.006 | 1,360 | $ 9.90 | $0.015 | 6,580 | $ 6.02 | $0.009 |
| III | 5,300 | 6.00 | 0 ** | 745 | 6.00 | 0.001 | 6,045 | 6.00 | 0.001 |
| IV | 5,395 | 6.00 | 0.005 | 2,976 | 4.50 | 0.004 | 8,371 | 5.56 | 0.0054 |
| V | 11,713 | 10.00 | 0.007 | 5,427 | 9.00 | 0.004 | 17,140 | 9.68 | 0.011 |
| VI | 8,675 | 24.00 | 0.027 | 3,657 | 7.00 | 0.004 | 12,332 | 18.96 | 0.031 |
| VII | 720 | 25.00 | 0.012 | 180 | 10.30 | 0.001 | 900 | 22.06 | 0.013 |
| VIII | 600 | 12.00 | .006 | 600 | 12.00 | 0.006 | 1,200 | 12.00 | 0.012 |
| IX | 2,682 | 9.00 | 0.01 | 657 | 8.00 | 0.003 | 3,340 | 8.80 | 0.013 |
| X | 950 | 12.70 | 0.027 | 50 | 3.50 | 0.001 | 1,000 | 12.00 | 0.028 |
| Total | 41,225 *** | | | 15,700 | | | 56,925 | | |
| Average | | $11.82 | $0.012 | | $7.67 | $0.003 | | $10.29 | $0.014 |
| Total Industry | $487,279.00 | | | $120,479.00 | | | $607,758.00 | | |

* Weighted – reflects off-site disposal only

** Reclaimed – cost to process averages $6.00/ton covered by sale of reclaimed product (6,740 tons)

*** Includes 6,740 tons reclaimed

into account in establishing an average cost. In other Regions on-site or reported low costs were eliminated from the average since it is expected that off-site secure landfills will be mandatory for most, if not all, rerefineries.

Table 44 shows extrapolated typical costs for Levels I, II, and III technology. Levels II and II assume fixation costs for both on-site and secure off-site landfill disposal. It is estimated that fixative chemicals double the sludge volume for both acid, caustic, and other sludge. Clay volume increases by 50%.

## 6.3 Industry Waste Treatment/Disposal Costs

The variations in disposal and product add-on costs listed in Table 43 are caused by several factors. Transportation costs in some instances are high because of distant landfill locations. Commercial and municipal landfill charges range from a reported zero to over $13.00 per ton. On-site disposal of untreated sludge and clay costs are as low as $1.00 per ton.

The table also shows weighted average disposal costs by EPA Regions using composite typical rerefineries with on-site and off-site landfill disposal. Off-site higher costs reflect the charges by landfill operators as well as transportation costs. In many, if not all cases,

## TABLE 44

### TYPICAL WASTE DISPOSAL COSTS & COSTS PER GALLON OF RE-REFINED OIL IN 1975
### TECHNOLOGY LEVELS I, II, & III

| Level | Sludge | | | | Clay | | | | Industry Extrapolation Total Cost | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Quantity (tons/yr) | Cost (ton) | Total Cost (tons/yr) | Cost Product (gallon) | Quantity (tons/yr) | Cost (ton) | Total Cost (tons/yr) | Cost Product (gallon) | Cost Waste (tons/yr) | Cost Product (gallon) |
| I.<br>On-Site | 41,225 | $ 3.00 | $123,675 | $ 0.0026 | 15,700 | $ 2.00 | $ 31,400 | $ 0.006 | $ 155,075 | $ 0.003 |
| Off-Site | 41,225 | 8.00 | 329,800 | 0.0065 | 15,700 | 8.00 | 125,600 | 0.0025 | 455,400 | 0.009 |
| II.<br>On-Site | 82,450 | 8.00 | 659,600 | 0.013 | 23,550 | 6.00 | 141,300 | 0.003 | 800,900 | 0.016 |
| Off-Site | 82,450 | 20.00 | 1,640,900 | 0.032 | 23,550 | 18.00 | 423,900 | 0.008 | 2,064,800 | 0.04 |
| III.<br>On-Site | 82,450 | 8.00 | 659,600 | 0.013 | 23,550 | 6.00 | 141,300 | 0.003 | 800,900 | 0.016 |
| Off-Site | 82,450 | 20.00 | 1,640,900 | 0.032 | 23,550 | 18.00 | 423,900 | 0.008 | 2,064,800 | 0.04 |

the use of approved or secure landfills requires transportation to areas much more distant than those municipal and commercial landfills which have been used by rerefiners. Many of the municipal and commercial landfills are no longer accepting rerefining wastes.

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## APPENDIX A
## COMMERCIAL REREFINERS - 1975

**Active**

1. Alco Refining Division
Bonus International
133 North First West
Salt Lake City, Utah 84114
801/343-0450
J. R. Mastulotto

2. Arrowhead Oil Refining Company
3519 Miller Trunk Hwy
Duluth, Minn. 55811
218/729-6122
William Heino

3. Bayside Oil Corporation
977 Branston Road
San Carlos, Cal. 94070
415/593-2944
A. Ray Banks

4. Berks Associates, Inc.
Box 617
Pottstown, Pa. 19464
215/385-3031
Lester Schurr

5. George T. Booth & Son, Inc.
76 Robinson Street
North Tonawanda, N.Y. 14120
George T. Booth

6. Cooks Oil Company
P.O. Box 156
Boyd, Texas 76023
Joseph Gillespie

7. Coral Refining Company
765 Pawnee Avenue
Kansas City, Kansas 66105
913/281-5454
Richard O'Blasny

8. Davis Oil Company
Box 1303, 1100 Orange Avenue
Tallahassee, Fla. 32302
904/576-3116
George Davis

9. Dearborn Refining Co.
3901 Wyoming Ave.
Dearborn, Mich. 48120
313/843-1700
G. O. Horton

10. Diamond Head Oil Co.
1427 Harrison Tpk
Kearny, N.J. 07032
201/991-5800
R. W. Mahler

11. Double Eagle Refining Co.
Box 11257
Oklahoma City, Okla. 73111
405/223-0244
Cameron Kerran

12. Fabian Oil Refining Co.
4200 Alameda Ave.
Oakland, Cal. 94601
415/532-5051
Bryan Fabian

13. Gurley Oil Co.
Box 3326
Memphis, Tenn. 38102
901/527-9940

14. Jackson Oil Co.
Box 5686
Jackson, Miss. 39208
601/939-3131
H. E. Robertson

15. Leach Oil Co., Inc.
625 East Compton Blvd.
Compton, Cal. 90220
213/323-0226
Roy Leach

16. Lubricants, Inc.
1910 South 73rd
W. Allis, Wis. 53214
414/691-3500
Richard W. Drexler

## COMMERCIAL REREFINERS

17. Motor Oils Refining Co.
7601 West 47th St.
Lyons, Ill. 60534
312/242-2306

18. Nelson Oil Refining Co.
1211 McKinley Ave.
National City, Cal. 92050
714/747-7511
Roger Humphrey

19. NuWay Oil Co.
7039 N.E. 46th Ave.
Portland, Ore. 77218
503/281-9375
A. L. Geary

20. Peak Oil Co.
Rte 3, Box 24
Tampa, Fla. 33619
813/671-7505
John Harris

21. Petrocon Corporation
P.O. Box 347
Valley Forge, Pa. 19481
215/383-5262
John Cunningham

22. Research Oil Refining Co.
3680 Valley Road
Cleveland, Ohio 44109
216/749-2777
Joe Fallenberg

23. S & R Oil Company
Box 35516
Houston, Texas 77035
713/729-8740
R. A. Sweasy

24. Seaboard Industries
Box 47333
4810 Peachtree Rd
Doraville, Ga. 30040
404/456-2241
Byron Cohen

25. Texas American Oil Co.
300 Westwall, Suite 1012
Midland, Texas 79701
915/683-4011
E. R. Fisher

26. Warden Oil Co.
187 Humboldt Ave. North
Minneapolis, Minn. 55405
612/374-1200
A. L. Warden

27. Westville Oil & Mfg., Inc.
Box 567 State Road No. 2
Westville, Indiana 46391
219/785-2334
Andrew Carson

## Inactive - Lube Oil Rerefining

1. Keenan Oil Co.
No. 1 Parkway Drive
Cincinnati, Ohio 45212
513/631-2900
S. R. Passell

2. C. S. McAuley, Inc.
P.O. Box 219
Downey, Cal. 90241
213/861-2103
C. S. McAuley

3. Midwest Oil Refining Co.
1900 Walton Road
St. Louis, Mo. 63114
314/427-2682
Glen Gettinger

4. Motor Guard Lubricants, Inc.
4334 East Washington Blvd.
Los Angeles, Cal. 90023
213/263-6877
Bruce Hoss

5. National Oil Recovery Corp.
Box 358
Bayonne, N.J.
201/437-7300

6. Talley Bros., Inc.
2007 Laura Ave.
Huntington Park, Cal. 90255
A. W. Talley

7. D. A. Stuart Oil Co. Ltd.
1509 South Senate
Indianapolis, Indiana
317/632-3613
R. C. Ragoff

# APPENDIX B

## DATA QUESTIONNAIRE PETROLEUM REREFINING WASTE STUDY

Company ____________________ Date ____________

Address ____________________ Ref. No. ________

____________________

Contact ____________________

A. Classification

Collector ____

Reprocessor ____ Method ____________________ (1)

____________________

Rerefiner ____ Method ____________________

____________________

B. Products %

Automotive ____

Industrial ____

Fuels ____

Others ____

Remarks ____________________

____________________

____________________

C. Waste oil received

| | 1st Qtr | 2nd Qtr | 3rd Qtr | 4th Qtr | Total |
|---|---|---|---|---|---|
| Crankcase | | | | | |
| Industrial (2) | | | | | |
| Fuels, Solvents | | | | | |
| Others | | | | | |

D. Rerefined Lube (3) ______________________________

Distillate ______________________________

Fuels, used ______________________________

Fuels, sold ______________________________

Water used ______________________________

Is distillate (fuel) treated? Yes ___ No ___

(1) If acid, is new or recycled acid used?
(2) Includes all oils other than crankcase oils
(3) Include only oils processed. Do not include virgin oils or additives

Remarks Section C and D

______________________________

______________________________

______________________________

|  |  |  | 000 Gal/lbs |  |  |
|---|---|---|---|---|---|
| E. Sludge produced | 1st Qtr | 2nd Qtr | 3rd Qtr | 4th Qtr | Total |
| Raw storage |  |  |  |  |  |
| Pretreatment |  |  |  |  |  |
| Distillate treat |  |  |  |  |  |
| Clay and filter aid |  |  |  |  |  |

| Disposal Method | % |
|---|---|
| Landfill | ___ |
| Road Oil | ___ |
| Incinerate | ___ |
| Fuel, internal | ___ |
| Other | ___ |

Describe ______________________________

______________________________

______________________________

______________________________

| | Yes | No |
|---|---|---|
| Does your State or local government require - | | |
| Commercial landfill permits? | ____ | ____ |
| On-site (your own) landfill permits? | ____ | ____ |
| Hauler permits? | ____ | ____ |
| Have you had problems with use of either commercial or on-site landfill? | ____ | ____ |

Describe ________________________________________________

________________________________________________

________________________________________________

Have you had your sludge analyzed Yes ____ No ____

F. Waste water

| | 000 Gal. | | | | |
|---|---|---|---|---|---|
| Waste water | 1st Qtr | 2nd Qtr | 3rd Qtr | 4th Qtr | Total |
| Raw storage | | | | | |
| Chem treat | | | | | |
| Steam strip | | | | | |

G. Disposal, water

| | Sanitary sewer % | Storm sewer % | Stream % | Ground % | Other % | Recycle % |
|---|---|---|---|---|---|---|
| Raw storage | ____ | ____ | ____ | ____ | ____ | ____ |
| Chem pretreat | ____ | ____ | ____ | ____ | ____ | ____ |
| Steam strip | ____ | ____ | ____ | ____ | ____ | ____ |
| Cooling | ____ | ____ | ____ | ____ | ____ | ____ |
| Ground | ____ | ____ | ____ | ____ | ____ | ____ |

| | Yes | No |
|---|---|---|
| Do you use and API, or similar, separator? | ____ | ____ |
| Do you treat waters for disposal? | ____ | ____ |
| If you had/have water processing facilities would it or does it allow for recycling of all waste waters (process) | ____ | ____ |
| (ground) | ____ | ____ |

Have you had your water analyzed?

Does your State or local government require permits for water disposal?

Does State or local government monitor your waste water?

If yes, underline

Occasionally    Regularly    Constantly    Never

H. Information, general
(Please read cover letter Section )

Have you investigated any other methods or processes for disposal or utilization of sludges or spent clay? Do you know of others (rerefiners, chemists, suppliers, contractors) who have worked on this problem? Some methods are vacuum distillation, solvent extraction, pyrolysis, emulsification. Uses are fuels, special lubes, roof coatings, water proofing and road surfacing. We will appreciate any information you have in this area even if it is not completely satisfactory. Please furnish names, addresses and a short description of the process or use.

I. Please list names, addresses of reprocessors known to you in your area.

## APPENDIX C

## COMPOSITION OF SOME LUBRICATING OIL ADDITIVES[3]

| Additives | Composition | Function |
|---|---|---|
| Corrosion Inhibitor | Zn and Ba dithiophosphates, dithiocarbamates, metal sulfonates and sulfurized terpenes | To react with metal surfaces to form a corrosion-resistant film. |
| Rust Inhibitor | Sulfonates, alkylamines, amine phosphates, alkenyl-succinic acids, fatty acids, and acid phosphate esters | To react chemically with steel surfaces to form an impervious film |
| Antioxidant | Sulfides, phosphites, amines, phenols, dithiophosphates | To inhibit oxidation of oil |
| Detergent | Sulfonates, phosphonates, phenates, alkyl substituted salicylates combined with barium, magnesium, zinc, and calcium | To neutralize acids in crankcase oils to form compounds suspended in oil |
| Dispersant | Alkenyl succinimides, alkyl-acrylic polymers, ashless compounds | To disperse contaminants in the lubricant |
| Metal Deactivator | Organic dihydrophosphines, phosphites, and sulfur compounds | To form protective film on running surfaces to inhibit reaction |
| Color Stabilizer | Amine compounds | To stabilize oil color |
| Viscosity Index Improver | Isobutylene polymers and acrylate copolymers | To retard loss of viscosity at high temperatures |
| Pour Point Depressant | Polymethacrylates, polyacrylamides, alkylated naphthalenes, and phenols | To prevent congealing of oil at low temperatures |
| Extreme Pressure Additive | Organic compounds with sulfur, phosphorous, nitrogen, halogens, carboxyl or carboxylate salt | To form low-shear strength film providing lubrication at start-up and at high bearing loads |

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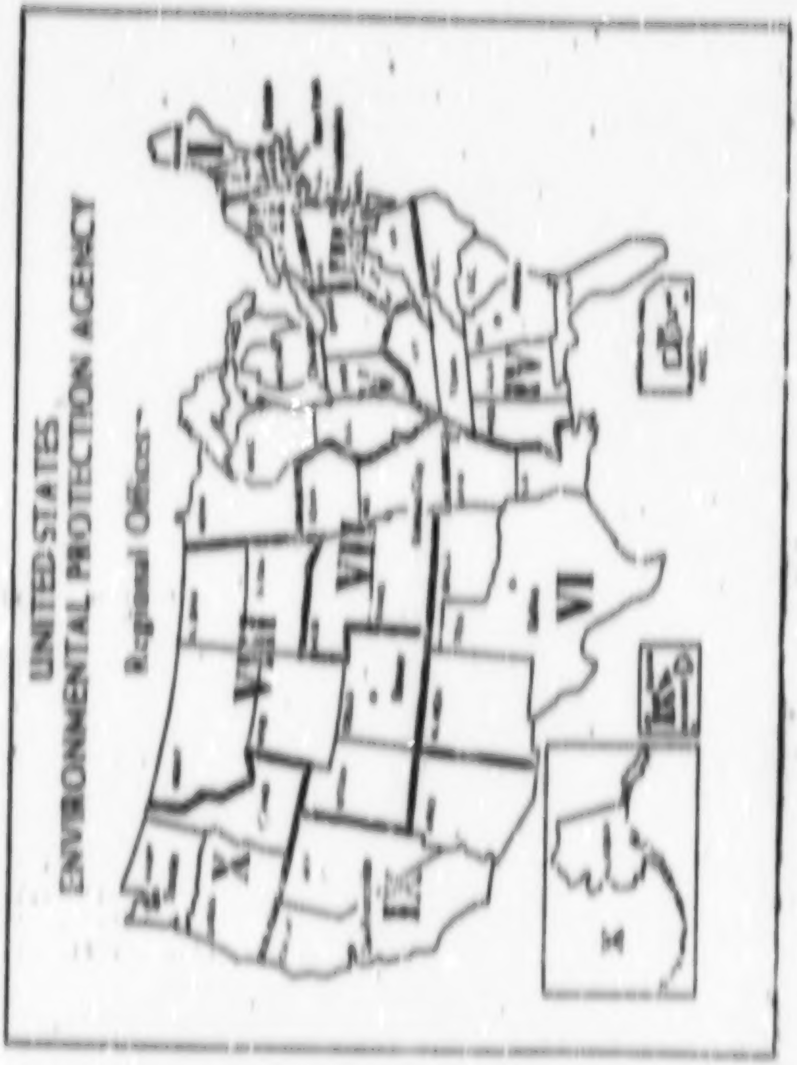
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# APPENDIX E

## GLOSSARY A

**Acid Number** = A measure of the inorganic and organic acidity of an oil using the quantity of a potassium hydroxide solution necessary to neutralize acids. See neutralization number ASTM D-974

**Acid Number, Total (TAN)** = A measure of the total acidic constituents in an oil; the milligrams of potassium hydroxide necessary to neutralize all acidic constituents in one gram of sample ASTM D-3339

**Additives** = Chemical compounds added to oils to improve operating characteristics (e.g., lubricity agents, detergents)

**Additive Package** = Two or more additives mixed by the additive manufacturer to impart desired characteristics of an oil (e.g., rust and oxidation inhibitor)

**API** = American Petroleum Institute

**APR** = Association of Petroleum Rerefiners

**Ash** = The amount of non-combustible material in an oil; that which remains after combustion under controlled conditions. An indication of impurities and the additive content ASTM D-874

**ASTM** = American Society for Testing and Materials; establishes analytical and other test methods for several industry products (e.g., petroleum, paints)

**Aviation Oils** = Lubricants used in aircraft engines; reciprocating internal combustion engines; used oils similar to those used in automobile engines. Jet engines use synthetic lubricants.

## GLOSSARY B

**Base Number, total** = A measure of alkalinity of an oil; the quantity of perchloric acid necessary to neutralize all basic (alkaline) constituents ASTM D-2896

Base Stock - Lubricating oils which are chemically treated (e.g., sulfurized, or with which additives are blended for specific products)

Bottoms - Residue from chemical or thermal distillation of oils. See sludge.

BS&W - Bottoms, Sediment, and Water - ASTM D-96 Laboratory standard method for measuring water and solids content of oils

## GLOSSARY C

Carbon Residue - The amount of carbon remaining after controlled evaporation of an oil; indicates carbon forming characteristic of an oil in use ASTM D-189 D-524

Centrifuge - A machine which separates materials of different gravity (i.e., oil and water or a liquid and solids by centrifugal action which increases the "G" force); used in the laboratory to measure solids, water, and separable sludge in waste oils

Clay - Specially produced powders used for removing color bodies, extremely fine solids, and for neutralizing acidic compounds in oils; includes Fuller's Earth, activated clay, and bleaching clay

Copper Corrosion - Determination of free sulfur and corrosive sulfur compounds using a standard copper strip immersed in the oil at specified temperatures ASTM d-130

Crankcase Oil - Used motor oils removed from combustion engines; also called crankcase drainings

Crude Oil - Usually used for virgin oil refinery feed stock but occasionally used by rerefiners for raw waste oils

Cutting Oils - Lubricating oils of relatively low viscosity used for machining of metals; usually contain additives, such as fatty oils, sulfur, and chlorine compounds

## GLOSSARY D

Dehydration - Removal of water from oil by chemical and/or thermal methods. See distillation.

Demulsifier - A chemical compound (surfactant) which aids in removing water from oil by change in surface tension which allows the finely divided and dispersed water droplets to coalesce and separate from the oil by gravity

Detergents - Chemical compounds added to lubricating oils which keep sludge, formed during use, in suspension and surfaces clean (e.g., automobile engine interior)

Diatomaceous Earth - A powder derived from fossil remains which is used in filtration to aid in removing solids too fine for removal by screen, paper, or cloth, and to improve filtration flow rate; also called filter aid

Dispersants - Chemical compounds similar to detergents but used more specifically to keep solids, moisture, and compounds formed during use in suspension in the oil

Distillate - The low boiling components (light ends) removed from an oil during distillation; in rerefining the distillate is similar to a No. 2 fuel oil or kerosene

Distillation - A thermal process in which oils in commercial rerefining are heated to 550°-650°F (atmospheric) to remove low boiling constituents (See light ends, distillate) as vapors to improve lubricating oil performance. Partial distillation in refining (650°F maximum) is usually conducted with an oil/clay mixture and introduction of

**Distillation (cont.)** = steam for stripping odorous compounds, such as mercaptans, and to aid in removing low boiling constituents. The residual oil, after filtration, is the rerefined base stock.

Total distillation, using temperatures in the 980° F range and high vacuum pressure, removes the lubricating oil fraction, as well as, low boiling components.

**Drainage** = Waste oil from internal combustion engines; also called crankcase drainings of crankcase oil (CCO)

## GLOSSARY E

**Emulsifier** = Compounds ranging from fatty oil soaps to synthetic detergents which aid in stabilizing mixtures of oil and water by reduction of interfacial tension. Some emulsions can be formed mechanically by high shearing action.

**Emulsion** = A mixture of oil and water which does not readily separate by gravity. In "oil in water" (O/W) emulsions, the small oil droplets are dispersed in the water; in "water in oil" (W/O) emulsions, the water droplets are dispersed in the oil.

**E.P. (Extreme Pressure)** = Denotes a quality of a lubricant which prevents metal to metal contact under conditions of high loading (e.g., gears); a function of selected additives

## GLOSSARY F

**Fatty Acids** = Organic acids derived from fatty oils

**Fatty Oils** = Oils derived from animal fat or plants (e.g., lard oil, tallow, castor oil); used to impart a higher degree of lubricity and extreme pressure lubrication. They are more prevalent in industrial waste oils than in automotive oils.

Feed Stock = Material used for a process such as distillation; in rerefining the pretreated waste oil. See pretreated oil.

Filtration = The method by which solids are removed from air or liquid wherein the solids are removed by a screen, cloth, or paper. Diatomaceous earth (filter aid) is often used on the screen, cloth, or paper to remove ultrafine particles.

Fire Point = The temperature at which an oil sample continues to burn after a controlled flame is passed over the oil surface. ASTM D-92 is the standard laboratory analytical method.

Flash Point = The temperature at which an oil shows a puff of flame using the ASTM D-92 standard laboratory method. The flash point of a lubricating oil is usually $40^\circ$-$50^\circ$F lower than the fire point.

Fuel, distillate = Petroleum fuels produced during distillation; includes No. 1 used in home heating and No. 2 used in home and some industrial and commercial heating units

Fuel, residual = Heavy fuels produced from the crude oil portion remaining after distillation; used in large industrial and commercial boilers and other heating units

## GLOSSARY G

Gear Oils = Oils used to lubricate gears. These contain additives such as sulfur, chorine, and phosphorus compounds, as well as, metals and soaps to provide the high lubricating requirements

Grease = Petroleum greases are mixtures of lubricating oils and soaps or thickeners; used where non-non-fluid lubricating is required. Presence of greases in waste oil streams can make reclamation difficult or economically unfeasible.

Gravity, API - The density of a petroleum product measured in API (American Petroleum Institute) units; related inversely to specific gravity in that the higher the API number the lower the density; used to denote quality, approximate hydrocarbon composition, and heat of combustion Test method, ASTM D-287

Grinding Oils - Oils used in forming of metal by grinding. Some grinding oils are emulsifiable and are used as a water mixture of soluble oils.

## GLOSSARY H

Hydraulic Oil - Oils used to transmit power and to actuate mechanisms; usually have suitable additives to reduce hydraulic pump wear, rusting, corrosion, and oxidation

Hydrotreating - The use of hydrogen to remove undesirable constituents such as sulfur and nitrogen from petroleum products under high temperatures and pressures in the presence of a catalyst; also called hydrofining. Potentially hydrotreating in rerefining could replace the final clay treatment.

## GLOSSARY I

Industrial Oils - Lubricating oils used in industrial machines for lubrication, power transmission, and machining; also used in railroad and marine engines and equipment

Inhibitors - Chemical compounds used in petroleum products to reduce oxidation, corrosion, rusting, among others

## GLOSSARY K

Kinematic Viscosity - See Viscosity.

Light Ends = Hydrocarbons, which are vaporized during distillation, that are removed and condensed. See Distillate fuel, kerosene. In rerefining, those low boiling constituents that are removed to produce a residual lubricating oil

Lubricity = That characteristic of an oil denoting its lubricating value (i.e., prevention of contact between moving surfaces)

## GLOSSARY M

Machining Fluids = See Metalworking fluids.

Mercaptans = Odoriferous sulfur compounds in petroleum oils. In rerefining, these are formed during distillation.

Metalworking Fluids = Combinations of oil and additives used for forming of metals by rolling, as in steel sheet or forms; forming as in pressing and forging; or machining, as in cutting or grinding. These may be so-called straight oils with various additives or chemical treatment of the oil, such as, sulfurization. Solubles, or emulsifiable oils are mixed with water for rolling, forming, cutting, and grinding. Solids, such as, graphite, mica, and talc are used with oil and soap mixtures for press forming of sheet metal or drawing of wire. Other terms used are cutting oils, grinding oils, rolling oils, drawing compounds, and forging compounds.

Motor Oils = Lubricating oils produced from base stocks with suitable additives for use in internal combustion engines, either gasoline or diesel

## GLOSSARY N

Neutral Oil = In rerefining, the oil distilled after light ends, or distillates, are removed. It is in the low viscosity lubricating oil range.

Neutralization Number - The measure of acidity or alkalinity of an oil measured by the amount of a potassium hydroxide solution or hydrochloride acid necessary to neutralize the acidic or alkaline (basic) components in the oil. The standard test method is ASTM D-974.

## GLOSSARY O

Overhead - The pipe lines which in distillation carry the light ends (distillate) vapors to and through condensors

Oxidation - The chemical process which changes the oil molecule by addition of oxygen. This is one of the causes of sludge and acid formation in motor and hydraulic oils.

Oxidation Inhibitor - Chemical compounds which reduce the formation of oxidized compounds

## GLOSSARY P

pH - The measure of acidity or alkalinity of an aqueous solution by indicating the hydrogen ion content. See Neutralization number, Total acid, and Total base number.

Parting Agent - Oil products used to prevent adhesion of an initially liquid material, such as concrete, plastic, or metal, to the walls of a mold. Waste oils are used for this purpose on concrete molds.

Polar Compounds - Chemical compounds which show a greater degree of chemical reactivity than petroleum oils. Fatty oils are such materials. In waste oils these are the compounds formed by oxidation or other chemical reactions during use, as well as, many of the additives blended with the base stock.

**Polymers** - Complex chemical compounds used in lubricating oils as additives to improve Viscosity Index (i.e., to reduce viscosity reduction with increasing temperature and to depress the pour point) (i.e., allow the oil to flow at lower temperatures) Polymers may form during use.

**Post Treatment** - In rerefining, the method used to produce a finished lubricating oil after distillation; in current rerefining practice, the removal of spent clay by filtration. It can include a secondary neutralization after distillation. Laboratory research indicates that hydrotreating after distillation can replace use of clay.

**Pour Point** - The temperature ($^{\circ}$F) at which a petroleum oil ceases to flow or begins to flow

**Pour Point Depressant** - Chemical compounds which depress or lower the temperature at which a petroleum oil ceases to flow. See Polymers.

**Pretreatment** - In waste oil processing, a process in which undesirable constituents of a waste oil are removed by chemical, physical, and/or thermal methods. Where pretreatment of a waste oil is the final stem, which may include filtration or centrifugation, the process is defined as reprocessing. In rerefining, the pretreated oil is the feed stock for distillation and clay treatment, or hydrotreating rather than clay treatment.

**Pretreated Oil** - Waste oil from which unwanted constituents have been removed by chemical, or other, action, resulting in a pretreated oil for distillation and post treatment to produce a rerefined oil and a sludge

**Process Oils** - Petroleum oils used either in processing (See Quench oils) or those added to products (e.g., ink, rubber, plastics, insecticides)

## GLOSSARY Q

Quench Oils - A process oil used in controlled cooling of steel parts which has been heated to high temperatures to improve hardness and other metallurgical properties

## GLOSSARY R

Reclaiming - Waste oil processing methods which improves waste oils and uses gravity settling, centrifugation, screening and heating at relatively low temperatures (100°-180°F) to remove water, solids, and oil insoluble sludge. Demulsifiers and other surfactants may be used but chemicals, such as sulfuric acid, sodium hydroxide, or sodium silicate, are not. The oil produced may or may not be defined as a clean fuel. See Reprocessing, Rerefining.

Reprocessing - Waste oil processing which uses higher temperatures (150°-210°F) with chemicals such as sodium hydroxide, sodium silicate, sulfuric acid, and, possibly, surfactants to remove water, solids, oil, insoluble and soluble unwanted constituents (e.g., additives and compounds formed during use) Reprocessed oils have applications such as clean fuel use, metalworking, and process oils, as well as, feed stocks for the distillation step in rerefining

Rerefining - Processes which produce a good quality lubricating oil from waste oil by pretreating (See Reprocessing) distillation, and clay contact or hydrotreating

Residual - In virgin oil refining, and in rerefining, the material remaining after removing lower boiling fractions (components). The residual in commercial rerefining is the lubricating portion after distillation at approximately 550°-650°F (atmospheric pressure).

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| Rolling Oils | = | Oils used in forming of ferrous and non-ferrous metals (e.g., sheet steel) These vary from straight fatty oils and petroleum oils with additives to emulsifiable oils. |
| Rust Inhibitors | = | Chemical compounds used to inhibit and prevent formation of rust. In petroleum products, these are used to inhibit rust formation in engines, hydraulic mechanisms, et.al. |
| Rustproofing Oils | = | Combinations of petroleum oils, and/or drying solvents, and/or waxes, and rust-proofing polar additives which are used to coat steel parts for prevention of rust formation during a storage period |

## GLOSSARY S

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| Sayboldt | = | A method of measuring the viscosity of an oil; units are Sayboldt Seconds Universal at standard temperatures (SSU @ 100°F, SSU @ 210°F). See Viscosity. |
| Sludge, Acid | = | The settled residue of reaction of sulfuric acid and unwanted constituents of waste oil; a black, viscous, acidic material containing solids and additives blended with the new oil and compounds formed during use |
| Sludge, Caustic | = | The settled residue of reaction of sodium hydroxide, and/or sodium silicate, or other alkaline compounds with waste oils; a grey to black, semi-gelatinous, neutral to alkaline material containing water, solids, and additives blended with the new oil and compounds formed during use |
| Sludge, Tank Bottoms | = | A combination of water, solids, and oil insoluble compounds which settles during storage of oil |

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| **Soluble Oils** | - Emulsifiable oils which, when mixed with water, are used as machining fluids, rolling oils, agricultural spray oils, and others |
| **Specific Gravity** | - See Gravity, specific. |
| **Steam Stripping** | - Steam introduced to oil during or after distillation to aid in removal of light ends and odoriferous and acidic constituents of the oil |
| **Sulfur, Actial** | - Sulfur in either elemental (or free) form or as part of a compound which is corrosive to copper. Provides E.P. (extreme pressure) properties; also called "added" sulfur, although not all sulfur compounds are active. Some sulfur (thio) compounds are oxidation inhibitors. |
| **Sulfur, Added** | - Sulfur, either elemental or an organic compound, which is added to the oil to meet operating requirements; found in machining fluids and such lubricants as gear oils which have severe operating requirements |
| **Sulfur, Natural** | - That sulfur which remains in the oil after refining or rerefining |
| **Surfactants** | - A term used for a wide variety of chemical compounds; surface active agents which reduce surface and inter-facial tension in oils, water, and oil/water mixtures |

## GLOSSARY T

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| **Tank Bottoms** | - See Sludge, tank bottoms. |
| **Total Acid Number** | - See Acid Number, total. |
| **Total Base Number** | - See Base Number, total. |

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| Transformer Oil | - Petroleum oil used in electrical transformers for insulation |
| Transmission Fluids | - Petroleum oils, containing suitable additives, used in power transmissions. Automatic transmission fluid for automoviles is designated ATF. |
| Transmission Oils | - Petroleum oils, containing suitable additives, used in manual power transmissions |

## GLOSSARY V

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|---|---|
| Viscosity | - The measure of the rate of flow of a liquid; technically, the internal resistance to flow. The test method and numerical definition consists of timing the flow of a measured amount of liquid at prescribed temperatures through a specific orifice. The traditional petroleum standard has been Sayboldt Seconds Universal (SSU). More recently, kinematic viscometers are used and measurements are expressed in centistokes (Cs) ASTM D-88 D-445 . |
| Viscosity Index | - The expression of the difference in rate of flow of a liquid at different temperatures and expressed as a number (e.g., V.I. 95) Petroleum oils are tested at 100°F and 210°F. The difference between the two viscosities is termed V.I. The lower the difference, the higher the V.I. |
| Viscosimeter | - Laboratory equipment used to measure the rate of flow of a liquid |
| V.I. Improvers | - Chemical compounds, usually polymers which reduce the viscosity with increased temperatures |
| Volatiles | - Those fractions of an oil which boil off (distill) at a given temperature; in petroleum oils, usually includes water and light ends |

# GLOSSARY V

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|---|---|
| Waste Oil | - Predominantly, petroleum products which have degraded in use so as to be unsuitable for the operating conditions. Waste oils can be derived from many sources with automotive and industrial oils comprising the largest volume. Fatty oils, synthetic oils, and solvents also contribute to the waste oil volume. |
| Wetting | - The ability of a liquid to spread on a solid surface; expressed in surface tension units (Dynes) |
| Wetting Agents | - Chemical compounds which increase the wetting power of a liquid. See Surfactants. |

## APPENDIX F

## EXPLANATION OF WASTE OIL GENERATION FACTORS

The estimates for the annual generation of waste oil have been calculated from those published in "Waste Oil Recycling and Disposal, EPA 670/2 - 74-052", August 1974. The author, Norman J. Weinstein, Recon Systems, Inc., based his estimates on information published by the United States Bureau of Census for 1971. The same assumptions and distribution percentages have been used by the author of this report. The Bureau of Census report "Sales of Lubricating and Industrial Oils and Greases, MA-29C(75)-1", September 1976, has been the source of the current estimates.

The author has changed some distribution percentages to reflect the increasing do-it-selfers engine oil market and the reduction in sales by service stations. Therefore, the market percentages for service stations has been changed from 24.8% to 19.8% of the automotive lube oil market. Discount sales have been increased by 5.0%.

Sales by garages and auto supply establishments have been increased by 2.0%. Factory fill sales has been reduced by 1.0%, reflecting the decrease in auto sales.

A reduction of 0.8% for car dealers' sales has been made for the same reason. Other minor reductions have been made which reflect the author's best judgment.

The lubricating oil sales and waste oil generation have followed the format used in the Weinstein report to offer a comparison between 1971 and 1975. The distribution used is not published by either the U.S. Bureau of Census or by petroleum industry sources. The waste oil generation factors used those based on the best judgment of the author of the 1974 "Waste Oil Recycling & Disposal" report. The author of this report does not necessarily agree with all of the waste oil generation factors, particularly those used for industrial oils. However, these are based on reasonable assumptions, and few industry figures are available; therefore these same factors have been used for better comparison between 1971 and 1975.

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